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CHEMICAL & METALLURGICAL ENGINEERING

New York, N. Y., Jan. 21, 1920 McGraw-Hill Co., Inc. Vol. XXII, No. 3, 20c. a copy

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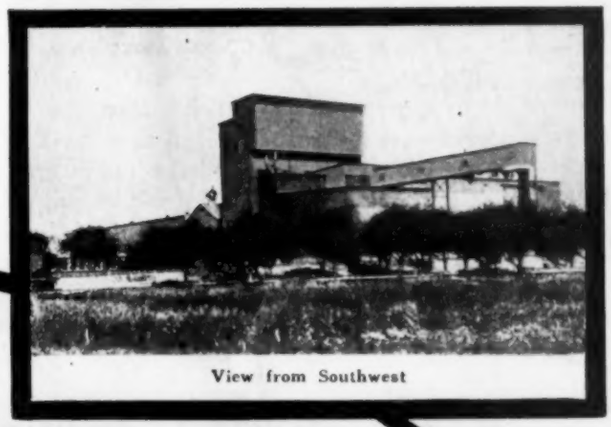

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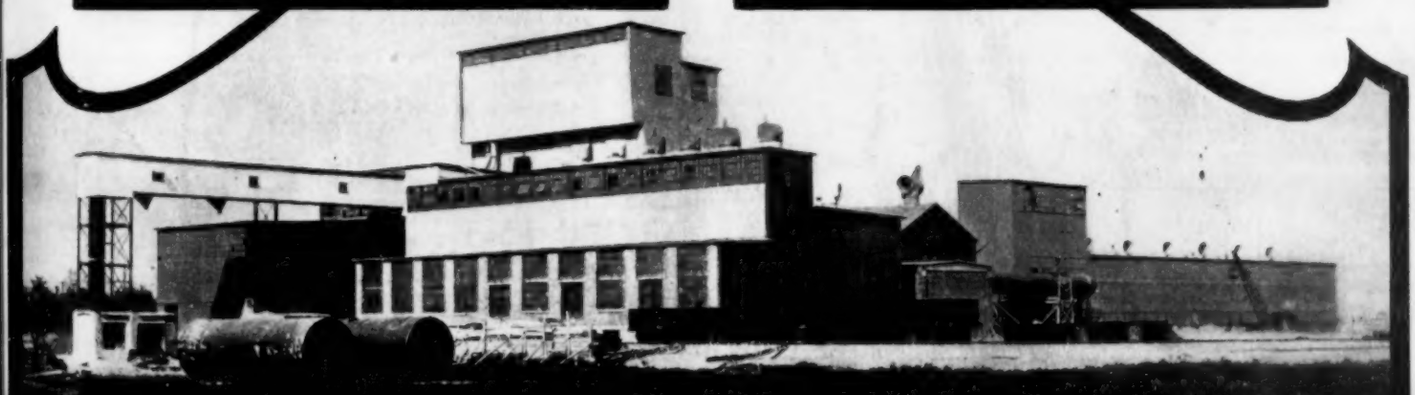

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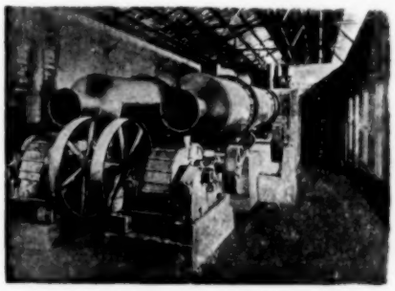

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Volume 22 — New York, January 21, 1920 — *Number* 3

Senate Passes The Water-Power Bill

BY A vote of substantially three to one the Senate passed on January 9 a bill for the development of water power in the United States. While the bill is not identical with that passed by the House last summer, there is agreement on essential points and there should be little difficulty in settling the difference in conference. The Senate bill provides for a Federal water-power commission consisting of the Secretaries of War, Agriculture and the Interior, which is authorized to license the development and operation of projects for a period of fifty years. At the expiration of licenses the Government has the right to take over the plant, issue a new license or permit continued operation under the old license. Licensees are to be required to pay an annual charge not exceeding twenty-five cents per developed horsepower, to reimburse the Government for the cost of administration and use and occupation of public lands necessary for the development of the project covered by the license.

One hesitates to grow too optimistic over this prospect of early enactment of water-power legislation. The subject has been debated for so many years that one emergency after another has found the country impotent to realize on its sources. Responsibility for the delay is being realized in the Senate, where Senator Williams declared recently during debate on the water-power bill that "the people of this country are gradually rising to the point where they demand abolition of the Senate for failing to function." But the Senate has now acted and it seems unlikely that much more delay will ensue, at least not more than is inherent in reaching agreement in conference. The national importance of the measure should spur the conference committee to early action.

More Power To the Chemist

ONE cannot read the remarks of OTTO EISENSCHIML before the Chicago Section of the American Chemical Society at the December 19 meeting under the subject "The Business Side of Chemistry," published in our last issue, without feeling that he has struck the keynote of greater success to the chemist and engineer in their dealings with the business world. The conditions under which business is done make every man engaged therein a salesman whether he desires it or not. Every word he utters in business connections, every move he makes, affects the sale of his personality with other people, whether it be conscious or unconscious. As the very foundation of business is the production of values, a man cannot be successful therein unless he is cognizant of the quantities and prices involved.

The chemical profession divides itself roughly into three classes: namely, the research chemist, who has to do with the production of values through new processes; the chemical engineer, who is interested in the installation of the plant for the successful production of the chemical, and the operator of chemical works, who has to do with the production and sale of chemicals when the plant is installed.

The research chemist may better his lot by demonstrating to his principals the value on a commercial basis of his discoveries. The chemical engineer, being by nature a business man, will collect deserved remuneration for the successful completion of the new plant. The operating chemist should be compensated for economies of operation effected or sales contracts consummated.

As Mr. EISENSCHIML stated, it is only a matter of business, which, in turn, is "common sense."

Wood Alcohol As a Beverage

THE recent fatalities in New England and New York resulting from the sale and consumption of certain intoxicating liquors containing wood alcohol should stimulate every chemist to use his individual influence in spreading information regarding the poisonous nature of this compound. To the chemist "alcohol" is a generic term and, since he is familiar with a large number of compounds belonging to this same class, the term is not necessarily associated in his mind with ethyl alcohol for beverage use.

Unfortunately, the public seems to be able to distinguish only two kinds of alcohol: denatured alcohol containing some evil smelling or ill tasting compound which obviously renders it unfit for human consumption, and alcohol which can be used in beverages. Wood alcohol, not being specifically designated as denatured (although, of course, it is used as a denaturing agent in many cases), is undoubtedly considered by many as belonging to the second class. The fact that containers of wood alcohol bear a label "poison" has even been explained by certain unscrupulous dealers as a ruse to prevent the Government from placing an internal revenue tax upon the contents. In order to prevent this confusion, manufacturing chemists have suggested to the Commissioner of Internal Revenue that the word alcohol be eliminated and that wood alcohol be known in future as "woodine." While this name may not meet with approval, viewed in the light of standard organic terminology, this action is a step toward the elimination of distinctions confusing to the non-technical mind.

Dr. REID HUNT, in a recent bulletin on wood alcohol, prepared at the request of the American Chemical Society, calls attention to the fact that the senses of

taste and smell cannot be relied upon to indicate the presence of wood alcohol and that poisonousness is an inherent quality of the substance, since it is oxidized in the human system to formic acid (and perhaps formaldehyde), while ethyl alcohol is converted into water and carbon dioxide, both harmless and easily eliminated.

In view of the serious consequences which may result from ignorance in this connection, every chemist should devote his energy to the enlightenment of the public regarding the dangers of wood alcohol.

It must be remembered, however, that wood alcohol or methyl alcohol has extensive legitimate uses in the field of chemical industry, and legislators and others should not lose sight of this fact in placing restrictions upon the sale and use of this commodity. The public must be protected, but the accomplishment of this aim must not result in the destruction of a legitimate industry.

Chemicals in A Smelter Flue

A PROMINENT metallurgist recently expressed the hope that the court order dissolving the packing trust might not react unfavorably in the smelting world to the extent of actually impeding recovery of byproducts, a work which he characterized as the most important now before technicians in this industry. His fears, however, appear somewhat magnified. Few Americans object to the slogan "Save all but the squeal," nor its actual realization, since conservation is fundamentally important. Rather, what they do object to is a manipulation of accounts so that economies in general operation are not reflected in the ultimate selling price of individual products to a method whereby the price of meat is all cost and the price of leather or blood all profit, and to a so-called publicity campaign showing that philanthropic butchers of great wealth make the merest trifle on their business. No one can reasonably object because a lead smelter saves, refines and markets its cadmium, and there is small danger of such a plant reaching out into various ramifications of the white-metal founding business because of this minor production. Then they should get into trouble, as have the packers when they market poultry because they have refrigerator cars and cold storage to handle them and strive to control the egg market because eggs are a poultry product. From this it is not a long step to the pillow business to get rid of feathers, and to the manufacture of beds and mattresses, in order to preserve a well-rounded market for the pillows. Thus it is that poultry is dear in order that an independent builder of brass beds in some corner of the country might be squeezed out of business!

Recover cadmium, a lead or zinc smelter must. Time was, and not so many years ago, that the cream of an ore was skimmed, and everything else slagged off, and what wouldn't slag went up in smoke and came down again to the detriment of the surrounding country. Nowadays, what with bag-house, dust chamber and Cottrell plant, very little of even the finest fume gets by, and it is only a question of time when smelter systems will build up to saturation with a dozen little-known and little-wanted elements and their compounds of low vapor tension.

Consider arsenic, as an instance. Any Montana smelter making a consistent effort to abate the dust nuisance rapidly overflowed with arsenic. Anaconda built a little plant fifteen years ago to re-treat some of the richest dust, but the ores even then produced more poison than the whole country could absorb, and a short run demoralized the arsenic market and left the company bare of outlet. As a matter of fact these Western stores of dirty arsenic were handy during the war, and even yet the price remains mysteriously high, but it is only a question of time before large producers of arsenic will actually be compelled to produce other compounds than the oxide. Ridding themselves of this substance will require the popularizing of new insecticides by exploiting their uniformity and low cost, easily possible in large-scale operation on less than valueless raw material.

Cadmium is another instance. Large quantities are available from zinc and lead plants, but no one knows what to do with it. During the war, a considerable amount was used in solders and white alloys in place of more expensive and scarcer metals, but with a relaxation of necessity, its consumption vanished. Again, who knows what tellurium is good for? Smelters have much more of it on hand than they want, but how can it be used?

These are but typical instances of some others which will arrive later. Truly, the utilization of byproducts is the most important now before technicians. But in many of these cases the problem will be broader than merely their isolation in comparative purity; it will comprise intensive research into the properties of the elements, their alloys and chemical compounds. When this is actually done, conservative chemical companies which are not now much interested in buying impure speiss offered by smelters need not expect too much sympathy from the public, which in the long run pays for the acid, the fertilizer, insecticide, alloys and chemical compounds now reposing in a smelter flue system.

Industrial Patriotism And Professional Folks

IN RECENT speeches and press articles, the duty of us folks who are Americans has been definitely pointed out by loyal and able men. The slogan "Industrial Patriotism" was sounded by Mr. JOHN W. O'LEARY in a talk to the chemists at the Chicago National Exposition of Chemical Industries. It doesn't really matter just what we call it or in what manner of words these thoughts of the quiet majority, that is, the middle classes, are expressed, but they are living up to the idea as called by Mr. O'LEARY.

And this appellation "middle classes" is only a name and no longer has any reference to the financial standing of its individuals. We refer mainly to the salaried people who make up this host, to the clerk, the office man, the stenographer, the engineer, the chemist, the professional man and others whose income depends on mind work in contradistinction to the laborer and the capitalist. Apparently the laborer refuses to think and the capitalist is becoming accustomed to paying someone to think for him.

Through all this turmoil and noise industrial, this "word-talk" of individuals with perverted ambitions, we have heard very little complaint from the middle-folks. Their average income is far below that of the hand-worker, who, by the way, has profiteered on the public funds quite as much as the capitalist. And why are these people silent? Not because they are

contented, not because their income is sufficient, nor yet because they do not desire the luxuries of life and a competency for declining years, do they labor patiently at the day's work.

It is because they are well-balanced folks, taught in many a school to think, so that from the examples of the past they can glimpse over the horizon of the future. They know that the reward surely comes in proportion to the effort exerted, that individual progress is in direct ratio to the application and that the progress of society must be evolutionary, never revolutionary. They ask no wage they do not earn, they scorn paternalism. They are busy working at research and study. It was GLADSTONE who said that if hard work was not genius it was a mighty good substitute for it.

Once we knew a humble shipping clerk, hight TOMMY JONES, pointing to no one in particular, who when asked what he did for recreation said, "Work, different kind of work." And he meant it. You can guess where TOMMY is today. What's the matter with the laboring man doing the same thing by adding head-work to his activities? We'll admit his job may be hard and the work sordid. He has only to start thinking to better himself. Self-education is easy in this age. If he hasn't the mental "pep" to "get on," the capitalist can't hand him an "automobile" salary for throwing a lever or swinging a pick. The capitalist, on the other hand, must use the power that is his with honesty and fairness. If he does not he will be elminated by the very laws upon which our business existence is founded.

Both sides of these controversies may well look toward the middle-folks then, as living exponents of real "industrial patriotism." Let them meet at the middle point of view, so to express it, with the soldiers on the job, who have "eyes front" toward the future achievements, and what's more, there is no stirring tune to carry them onward, except, mayhap, the music of the inspired soul.

Steel Supplies
Recent and Prospective

EVEN to those who have followed more or less closely the course of iron and steel production in the past year it must come as a shock to observe that only about 30,000,000 tons can be counted up as the year's pig iron production, while the production of steel ingots and castings can be set at only about 33,000,000 tons. The output of ingots alone in the first half of the year was about 17,500,000 tons.

These figures for pig iron and steel are barely more than three-fourths those of 1916, and since then the productive capacity has been materially increased, so that the outputs are only two-thirds the present capacity, estimated upon a conservative rather than an optimistic basis. In 1917 and 1918 full outputs, in relation to capacity, were not realized on account of various difficulties incident to the times. In 1919 the United States had no foreign war on hand, but it did not have peace at home.

These figures, showing such a wide gap between production and capacity, certainly have a bearing upon the iron and steel market. In many quarters it is being argued that the iron and steel industry is marked for much higher prices. Pig iron has, in fact, advanced fully $8 a ton since July 1, and some observers insist that if steel prices have not advanced, that is only because the United States Steel Corporation has been holding them down. The corporation is very strongly of the opinion that steel prices should not go above the March 21 schedule, arrived at by an agreement between Secretary Redfield's Industrial Board and representatives of the industry, and that if possible steel prices should even be reduced. The Steel Corporation backed up its theory by selling nearly 1,500,000 tons of its products in November, none of the sales being at above March 21 prices.

If an argument that iron and steel prices should be higher in future is based upon a claim that capacity production cannot be realized, on account of various drawbacks, the alleged drawbacks should be plainly stated in order that investigation may be made to determine whether or not the same influences may apply to operations by the consumers of steel. On the whole, it is probable that more work is done on steel to fit it for use than is done in producing it. In other words, the total value of all steel at the moment it is put into employment is probably much more than double its value at the time it leaves the steel mill. If there is going to be a shortage of labor at blast furnaces and steel mills, will there not also be a shortage of labor for making extensions to railroads, for building skyscrapers and for making and using all manner of tools in all manner of industries?

All along the line costs are very high, but the steel industry has also a very heavy overhead. This matter of overhead impels the steel producer to seek large tonnage outputs, but many classes of steel consumers are not similarly influenced. A railroad does not make improvements for the sake of reducing overhead, nor does the factor apply in the case of new building construction.

It seems clear that the fact that production of iron and steel in 1919 has been only two-thirds of the capacity is not an argument that market prices should advance. It is true that steel is very scarce at the moment, but that condition is due to two temporary influences, namely, the iron and steel strike and the coal strike.

Whatever the bearing of production upon the market, however, it behooves all iron and steel producers to seek the greatest tonnages in relation to plant facilities. There has been enough of inefficiency and slackening. As regards its equipment the iron and steel industry is well aligned for full production. There are no weak links in the chain from the raw materials in the ground clear to the finishing departments, though there may be some finishing departments that should have larger capacity, both in relation to demand and in relation to the capacity to produce crude steel. The Lake Superior iron ore mines are capable of producing all the ore needed by the tributary furnaces, the lake fleet is of sufficient capacity, and in the matter of coke many by-product ovens have been built in the past few years and very few beehive ovens have been abandoned. Pig iron capacity is at least 40 per cent greater than before the war, and more than 10 per cent greater than the maximum output yet recorded for a year, while it is quite possible that under favorable conditions the furnaces may exceed ratings based on past performances. Steel producing capacity is at least 40 per cent, perhaps 45 per cent, greater than it was in 1914. Efficient management and efficient labor are the two remaining desiderata for a remarkably heavy production by the industry.

Readers' Views and Comments

Atomic Structure of Metals in Solid Solution

To the Editor of Chemical & Metallurgical Engineering

SIR:—I have read with much interest the paper in your Oct. 29-Nov. 5 issue on page 566, on the "Atomic Structure of Metals in Solid Solution," by A. E. Feild. While I feel that Mr. Feild's paper will stimulate thought along the lines of interpretation of the properties of solid solution alloys, I cannot agree with some of his general conclusions which would indicate that solid solution alloys consist largely of the amorphous phases of the components. The illustrative example given in his Fig. 2 shows the electrical resistivity of the solid amorphous metal and the solid crystalline metal diverging with decreasing temperature. This is admittedly an illustrative example. In his Fig. 3, however, where the actual examples of gold and silver are cited, the electrical resistivity of the solid amorphous phase and the solid crystalline phase converge with decreasing temperature. As pointed out in one of my papers[1] the convergance of several properties is the rule immediately below the freezing point of the metal, and I am wondering whether any actual examples exist in conformance with the illustrative example shown in Fig. 2.

On page 569, Mr. Feild writes: "A solid solution may then be regarded as entirely analogous to a super-cooled liquid preserving in the solid state all of the electrical properties such as specific resistance and temperature coefficient of resistance of the molten mixture of the components." Farther on he states: "According to our theory hardness in such an alloy is due to the existence of the metal in the amorphous solid state, thus confirming essentially Beilby's theory of the formation of an amorphous phase during cold working of a metal.

"In accordance with this view gamma iron is simply amorphous solid iron which is in solid solution with carbon."

Mr. Feild seems to have entirely ignored the directional and deformational properties of solid solution alloys, their appearance under the microscope, the heat of crystallization on solidification and the heat of fusion on melting, the grain growth phenomena after deformation, the usual crystallization shrinkage on solidification, etc. It might also be expected that an alloy of equal atomic proportions of silver and gold, for example, would show a sharp break in electrical resistivity at the melting range and that Mr. Feild's calculations based on the extrapolation of the electrical resistivity of the amorphous phase from the melting point down to room temperature would not hold at a temperature immediately below that of freezing. Mr. Feild's general conclusions, therefore, are untenable in the face of the existing evidence of the crystalline nature of solid solution alloys.

I do not maintain, however, that the existence of amorphous films between the grains of solid solution metal does not play an important role in the observed properties of solid solution alloys, nor that the atoms in the solid solution crystal are arranged in the same manner as the atoms in the crystals of the pure components. It is highly probable that the electrical and other properties of metallic solid solutions will be explained on the basis of an atomic arrangement and an electron distribution consistent with the present observations on the crystalline nature of solid solution alloys."[2][3][4]

Cleveland, Ohio. ZAY JEFFRIES.

[1] "Effect of Temperature, Deformation and Grain-Size on the Mechanical Properties of Metals," *Trans.*, A. I. M. E., vol. 60, 1919, pp. 474-576.

[2] See P. Ludwig, *Z. Ver. deut. Ing.*, vol. 63, pp. 142-144, Feb. 15, 1919.

[3] C. Viola, *Atte. Accad. Lincei.*, vol. 261, pp. 195-207 (1917).

[4] H. C. Burger, *Physik. Z.*, vol. 20, pp. 73-75, Feb. 15, 1919.

Sulphuric Acid Nomenclature

To the Editor of Chemical & Metallurgical Engineering

Sir:—I have read with much interest the views of Thomas J. Sullivan on "Sulphuric Acid Nomenclature" which I heartily indorse. There is no doubt that there is great confusion in the terms of the various strengths of this important acid, but practically all of this could be avoided by referring to all strengths up to fuming as per cent H_2SO_4 and above this as equivalent H_2SO_4.

Newark, N. J. R. ZELLER.

A New Compensated Heatmeter

To the Editor of Chemical & Metallurgical Engineering

SIR:—In the Oct. 1 issue of CHEMICAL & METALLURGICAL ENGINEERING, a letter to the editor appeared, in which its author, Mr. T. S. Taylor, severely criticises our use of "Heatmeter" as a name for a new instrument of our manufacture. He claims that it is a misnomer, and misleading because heat is not measured quantitatively by means of the apparatus.

Kindly allow us space to explain that in utilizing "Heatmeter" as a trade name, this company merely availed itself of well-established precedents, and adopted a term quite as accurate and descriptive as many others of common usage in pyrometry; such as, for instance, "Multi-Pyrograph," "Hot-Spot-Potentiometer" and "Pyro-volter."

If it were expedient to quibble about the etymology of terms for designating special apparatus in any art, we could appropriately begin with the word "pyrometry," which literally means fire measurement, but I note that Mr. Taylor does not take exception to or comment on its ambiguity.

There are many other technical terms which should be banned, if Mr. Taylor's complaint were valid. For example, a "storage battery" does not store electricity; a "dry cell" is not dry; a "phonograph" does not write sound; a "potentiometer" does not serve to measure, but to balance, potentials; an "electrometer" is not a meter, but a means for comparing the intensity of static charges; and finally, the good old word "thermometer" must be deplorably misleading, because its derivation, from the Greek θέρμη" and the French "métre" makes it identical in its definition with "Heatmeter," and yet nobody is likely to imagine that either of these instruments may be used for the direct determination of thermal units. Hence our reputation is probably not at stake.

High school boys, Mr. Taylor admonishes us, are taught to appreciate the nice distinctions of nomencla-

ture in physics classes. This may be the case; but it may be interesting to learn that it was one of our most distinguished professors of rhetoric and philology at Harvard, who, in lecturing on colloquialisms and slang, told us that expressions such as "open circuit," "lost motion," "booster," "split phase," a "baking frost" and a "frozen bearing" were entirely permissible, and declared in substance that philologists admit that utility, rather than derivation or euphony, determines the adoption of new words or phrases which will constitute a succinct addition to our vocabulary.

Mr. Taylor also asserts I stated that an ammeter takes the place of a pyrometer in the "Heatmeter." If he reads my article carefully, he will note that I used an ammeter merely to demonstrate the fundamental principles of the Harrison-Foote invention in an elementary manner, and that the text describes the instrument as a modified form of precision millivoltmeter or pyrometer.

CHARLES P. FREY,
Chief Engineer,
The Brown Instrument Co.
Philadelphia, Pa.

Controversy Over Dye Licensing System

From the extensive hearings which were recently concluded before a sub-committee of the Senate Committee on Finance, it is very clear that both political parties are perfectly willing to safeguard the domestic dye industry, but that the question of method is very certain to bring on a determined fight when the bill comes before the Senate. The licensing system which it is proposed to apply to the dyestuffs industry will be the chief obstacle to the bill's speedy consideration. Unquestionably more than a majority of the Senate is opposed to licensing, but that they are willing to make concessions in certain cases has been shown by the attitude of many Senators, opposed to the principle of licensing, in the matter of continuing the licensing plan of handling of sugar. Many recognize the dye situation as presenting an exception, and it is not improbable that the Senate may adopt the general plan as set forth in the Longworth bill, which already has passed the House.

Joseph H. Choate, Jr., counsel for the American Dyes Institute, pointed out to the committee the success which has attended the administration of the licensing system in England and France.

General Sibert, in an argument for the stimulation of the dyestuff industry, declared that every chemical plant is a potential arsenal. Admiral Earle testified that the average time to convert a dye-making plant to war uses is three weeks. In a letter to the committee, the Secretary of the Interior urged early legislation. Van H. Manning, the director of the Bureau of Mines, appeared before the committee and pointed out the imperative need for legislation which would stabilize and stimulate the dyestuff industry.

Colonel Fries of the Chemical Warfare Service declared that the effectiveness of the United States in the war was lowered by lack of chemists. Even at the end of the war, he asserted, there had not been enough chemists developed to more than begin to handle the work. Colonel J. H. Burns of the Ordnance Department told the committee that the United States has been behind first-class powers in chemical knowledge.

Dr. M. T. Bogert, professor of organic chemistry at Columbia University, expressed the opinion that the coal-tar industry would have to have protection for ten years largely because of the time required to develop skilled men. He also pointed out that among the 15,000 trained chemists in the United States, not over 10 per cent are trained organic chemists. Dr. Julius Stieglitz of the University of Chicago, testifying in regard to synthetic drugs, declared that many lives and much suffering could have been prevented had we developed our chemical industry in the past. Henry Howard, representing the Manufacturing Chemists' Association, told how the Germans, prior to the war, used our patent laws to maintain a monopoly for their own country on dyestuffs. Henry Wigglesworth, also of the Manufacturing Chemists' Association, believes the licensing can be better administered by a board such as was provided in the original Longworth bill rather than placing the administration of the act in the hands of the Tariff Commission.

The main points made by those opposing the licensing system were that it is in reality an embargo under a different name; that no commission, no matter how composed, could administer a licensing system for dyes without doing great injury to the industry. Not only would the system be cumbersome in operation, it was declared, but it would place an army of $1,500 clerks in control of an important portion of America's business. The effect of the legislation would be very harmful to export trade, it also was stated.

Meeting of A. I. M. E., New York Section

The New York Section of the American Institute of Mining and Metallurgical Engineers held its regular monthly meeting at the Machinery Club, Jan. 7, 1920. Walter C. Perkins spoke on the co-operative system in Russia and gave a very interesting account of the method of organizing co-operative associations in commerce, industry, banking, etc. This method of conducting business has proved highly efficient even among the illiterate peasants of Russia. It has not been popular with the Soviet government, which has made every effort to destroy it. Mr. Perkins was of the opinion that the co-operative system is the best hope for the regulation of the cost of living, eliminating the usurer and the middleman.

Percy H. Thomas described the power development at the Chuquicamata and Braden copper properties in Chile. Natural conditions at the two properties are quite different and call for different types of plant. At Chuquicamata the absence of rivers and the desert nature of the country dictate the construction of a steam-power plant at tidewater, with oil for fuel, and a transmission line to the mines. At Braden, on the other hand, with a plentiful supply of water, a hydroelectric plant was called for. Mr. Thomas illustrated his talk with several reels of film.

Regulation of Engineering Practice by License Issued Under State Laws

In compliance with the instructions of Engineering Council, a committee to frame a uniform bill on the licensing of professional engineers met recently in Chicago. There have been a number of bills introduced in the several state assemblies and about eleven of these have become laws, several of which have been so drafted as to work unnecessary hardship. It has therefore been considered advisable to draft a model bill for introduction by those interested in the various states, in order to supplant or forestall enactments of indifferent origin or harmful results.

Theory and Practice of Catalysis

THE meeting on Jan. 9 of the New York Section of the American Chemical Society was well attended, Rumford Hall being filled to its capacity. Dr. Ralph H. McKee, chairman, opened the meeting. Secretary Herbert G. Sidebottom read the minutes and treasurer's report. He announced that the membership of the section was 1,990, but ten short of giving to the section a twenty-first representative to the Council.

The evening was devoted to papers on Catalysis, the theoretical physicochemical backgrounds being concisely presented by M. Harvey, a preliminary report on the catalytical oxidation of benzene at the Research Laboratories of The Barrett Co. by John M. Weiss and Charles R. Downs, and the action of driers in paints and varnishes by F. P. Ingalls.

Mr. Harvey opened his paper with a discussion of the mass action (1) of the Deacon chlorine process[1]:

$$4HCl + O_2 \leftrightharpoons 2H_2O + 2Cl_2$$

$$\frac{dx}{dt} = k(a - x)(b - x) \qquad (1)$$

where a and b are the initial, x the reacted quantities and $\frac{dx}{dt}$ the velocity. He then stated the gas equation derivative (2) and the fundamental physical law (3) showing the relation between velocity, force and resistance.

$$0.058 \log \frac{P_{O_2} P_{HCl}^4}{P_{H_2O}^2 P_{Cl_2}^2} = 2.3 \log T - \frac{27300}{T} + \text{const.} \qquad (2)$$

$$\textit{Reaction Velocity} = \frac{\textit{Chemical Force}}{\textit{Chemical Resistance}} \qquad (3)$$

From these three equations it can be seen that reaction can be increased in three ways, by increasing the concentration in (1), the temperature in (2) or decreasing the resistance in (3). The action of the Haber ammonia process was explained.

$$N_2 + 3H_2 \leftrightharpoons 2NH_3 + 24{,}400 \text{ Cal.}$$

The reaction is one of chemical compression; 4 mols. of nitrogen and hydrogen being changed to 2 of ammonia with an accompanying heat discharge. Table I is a record of percentage yields of ammonia with changes in temperature and pressure. It will be noted

TABLE I. HABER PROCESS YIELDS

Pressure	550° C.	650° C.	750° C.	850° C.
1 atm	0.07	0.03	0.01	0.009
100 atm	6.7	3.02	1.54	0.87
200 atm	11.9	5.71	2.99	1.68

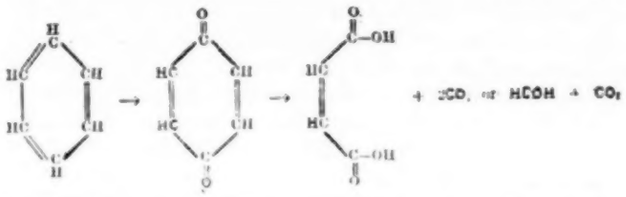
that lower yields are obtained at higher temperatures due to the heat of the reaction not being absorbed as the cooling head is diminished.

The hydrolysis of ethyl acetate in the presence of HCl was discussed from the oxonium and ion-hydrate theories of Falk and Nelson,[2] and H. Goldschmidt.[3]

Photochemical reactions were briefly touched upon from the quantum theory viewpoint. The formula[4] derived by Planck for radiation density was the basis of the discussion.

Mr. Weiss reviewed the literature relative to the previous work done on partial oxidation of hydrocarbons as a means of forming hydroxyls, ketones and new products. No practical results were obtained until 1907, when Orloff in Russia succeeded in producing products from cyclic ring petroleum. The year following the Bayer company took out patents showing that their research laboratory was investigating the field.

It was decided to concentrate on benzene during this investigation because it offered the simpler reactions. The scheme of these is shown graphically in the accompanying drawing. More details than can be given here will be found in the patents recently issued to the authors.[5] The catalyst used consisted of vanadium oxide on pumice. The reaction temperature was between 300



and 500 deg. C. Quinone and maleic acid are produced and seem to have an equilibrium ratio, though higher temperatures and increased amounts of oxygen tend to increase the yield of products of decomposition. The chief difficulty found in controlling these partial reactions is in absorbing the heat generated so as to keep within the temperature limits. In the formation of quinone from benzene 3,000 calories are liberated, and 10,560 in that of maleic acid, while 18,000 are given off in the total combustion to carbon dioxide and water. Very small yields of formaldehyde were obtained, due no doubt to its great reactivity with oxygen at the temperatures used.

The quinone is reduced to hydroquinone, which has a ready market as a photographic developer. The maleic acid is an intermediate for synthetic tartaric and citric acids. The Barrett Co. does not plan to manufacture these derivatives, but will be glad to supply any manufacturer with either the quinone or maleic acid.

The oxidizing action of steam at high temperatures and pressure on benzene was also studied.[6] At 60-lb. pressure and 690 deg. C., 23 parts of C_6H_6 vapor and 27 parts of H_2O gave a fair yield of diphenyl. No phenol was produced. This process furnished an interesting basic study for accounting for the large amounts of tar acid in Scottish tar.

F. P. Ingalls was highly entertaining as well as instructive in his paper on oil driers. He gave the action of lead, manganese and cobalt linoleates as well as the several other so-called oxidizers that have been tried out but not found to be oxygen carriers when in oil. Vanadium and cerium proved to be of no value. Lead ethylate also gave no results. The resinates of lead, manganese and cobalt were valuable, but unfortunately are quite susceptible to adulteration. The older method of boiling the oil with the drier metal oxides has largely been superseded by saponifying the oil and precipitating the linoleates by adding salts of the metals. These are dissolved in turpentine and mixed with the paint or varnish in such proportions as the drying time calls for. Linseed oil containing 0.075 per cent cobalt will dry in 2½ hr., so it will be seen that cobalt is a drying accelerator. Lead is the slower drier, but is preferred because of its smooth film. Paint that hardens too quickly tends to crimp. This is very noticeable with chinawood oil, which when applied to glass gives a somewhat frosted appearance.

[1] *J. Am. Chem. Soc.*, vol. 28, p. 380; 1906. *Zeit. Phys. Chem.*, vol. 59, p. 313; 1907.
[2] *J. Am. Chem. Soc.*, vol. 37, p. 1732; 1915.
[3] *Zeit. physik. Chem.*, vol. 60, p. 728; 1907.
[4] System of Physical Chemistry, Lewis, III, 1, 39.
[5] Weiss and Downs, U. S. Pat. 1,318,631-33
[6] U. S. Pat. 1,322,983.

Dr. Charles F. Chandler Receives the Perkin Medal

After introductory remarks by Charles E. Sholes, chairman of the New York section, at the fourteenth annual Perkin Medal presentation meeting of the Society of Chemical Industry, Friday night, Jan. 16, and some humorous reminiscences by Dr. M. C. Whitaker, who has been intimately associated with Prof. Chandler for the past twenty years, the Perkin Medal was graciously presented to Dr. Chandler by Prof. Marston T. Bogert of Columbia University.

Dr. Whitaker brought back to mind many incidents illustrating Prof. Chandler's fine personality, generosity, tact and greatness. Prof. Bogert gave a beautiful biographical sketch, reviewing back from 1637, when Dr. Chandler's forefathers came to New England, his early education and schooling at the New Bedford schools, the Lawrence Scientific School, Berlin, Göttingen and lastly his fifty-odd years as a university professor, and dean as well as world-wide chemical councilor.

Dr. Chandler gave an excellent example by presenting his acceptance address extemporaneously. He modestly stated that he had never considered himself as a candidate for the great honor that had just been conferred upon him. He then reviewed incidents taken at random from his life work which he humorously stated might excuse the medal committee. The outstanding features of Prof. Chandler's educational work along with his service as private and civic consultant are no less than monumental and are known to all American chemists about as well as the deeds of Washington. The flash point of lamp oils, ton assay weights, 66 deg. sulphuric acid, Baumé scale standardization, city plumbing regulations, sanitation, plant nuisances, and hundreds of other subjects were initiated by his genius. His titles, "Father of the American Chemical Society," "Dean of American Chemists," are tokens of esteem which can never be represented by even the most precious of metals cast in medals. For a fuller account and the addresses of the meeting, the reader is referred to our next issue.

National Academy of Sciences Establishes a Section of Engineering

The National Academy of Sciences has established a section of engineering. Despite all the comedy definitions from which the engineering professions suffer—a famous toastmaster was described in pre-prohibition days as "Digestion's Engineer"—the fact remains that engineering must be included under the general title of science. If this proposal had been made in the National Academy ten years ago there would probably have been recorded a number of fainting fits among its members. The committee consists of Messrs. H. L. Abbott, J. J. Carty, W. F. Durand, J. R. Freeman, H. M. Howe, F. B. Jewett, G. O. Squier and D. W. Taylor.

New Classification for Chemical, Physicochemical and Physical Phenomena

In the *Journal* of the Washington Academy of Science P. V. Well proposes a new classification for chemical, physicochemical, and physical phenomena, on the ground that recent advances have made the distinction between physics and chemistry both difficult and artificial. He proposes that all forces be classified as respectively, 1, molar; 2, molecular; 3, atomic; and 4, electronic. The corresponding sciences would then be molics, moleculics, atomics, and electronics.

Congress Investigates Expenditures For Nitrate Plants

A SUB-COMMITTEE of the House Committee on Expenditures in the War Department met at the Custom House, New York, Jan. 9-10 for the purpose of investigating the expenditure of $84,000,000 for the two nitrate plants at Muscle Shoals, Ala.

Frank S. Washburn, president of the American Cyanamid Co., testified that his company had offered to build Plant No. 2 with no thought of making a profit, during war time. Government officials decided, however, that the company was entitled to some recompense. As a result, the American Cyanamid Co. received a fee of $1,500,000, of which, Mr. Washburn said, about 85 per cent was deducted in taxes of various sorts and extra expenses cut into the remainder, so that the company made practically nothing. In addition, a contract was drawn up whereby the plants might be operated on a royalty basis by a subsidizing company acting as agent for the Government, for the production of nitrogenous fertilizer materials. The royalty to be paid to the American Cyanamid Co. until its patents expire is ¾c. per lb. of contained nitrogen.

When questioned as to the choice of Muscle Shoals for the location of Plant No. 2, Mr. Washburn pointed out that the simultaneous occurrence of abundant water power and deposits of high-grade limestone and coking coal within sixty miles made the situation unique from the point of view of raw material supply. Labor was also plentiful at the time the project was under consideration.

Possibility of Government Operation

The Government is interested in the manufacture of nitrogenous fertilizer materials under the contract already referred to. As a result of a study made by his company, Mr. Washburn was able to place before the committee statistics from which he had drawn the conclusion that the American Cyanamid Co. can purchase ammonia in the open market for a term of years cheaper than it can produce this compound from cyanamide. Hence, even under Government operation, the plant could not compete with the byproduct coke plants in the production of ammonium sulphate. In Mr. Washburn's opinion, Government manufacture of cyanamide would probably ruin the American Cyanamid Co., since the sale of cyanamide as such is limited (it being used exclusively in mixtures with acid phosphate) and the market is at present nearly saturated, 60,000 tons a year being produced by this company.

Bernard M. Baruch, chairman of the War Industries Board, discussed the nitrate problem during the war period briefly as follows:

Nitrate Program of War Industries Board

Sodium nitrate was admittedly the most important raw material which had to be obtained outside the boundaries of the United States. It soon became evident that Chile could not be depended upon, and a study of synthetic processes was undertaken. It was felt that, even though no plants were built, the knowledge of this possibility would prevent the Chilean producers from increasing their prices for fear of loss of trade in post-war times. With the enormously increased demand for propellants in the spring of 1918, Mr. Baruch saw that there was no possibility of even

the total production of Chile meeting the demand, and asked for four to six ammonium nitrate plants, each to have a capacity equivalent to 225,000 tons of sodium nitrate per year. These recommendations were made solely for the purpose of providing an adequate supply of nitrates for military purposes, and no thought as to the possibility of the cessation of hostilities was allowed to influence the decision. The matter of salvage was also considered of secondary importance.

Joint Committee on Ceramic Research

The National Research Council and the American Ceramic Society have established a joint committee for promoting the investigation of scientific problems underlying the ceramic industry, especially by founding a series of research fellowships whose holders shall devote their attention exclusively to these problems. The members of this committee are: A. V. Bleininger, chairman, ex-officio; Arthur L. Day, Homer F. Stanley, R. B. Sosman, E. W. Washburn, secretary, University of Illinois, Urbana, Ill.

The ceramic industries, including brick and tile making, and general crockery and glass manufacture as well as ornamental potteries, although among the earliest developed by man, have been the last of our great manufacturing industries to reach the status of applied sciences. They have been based for centuries on rule-of-thumb methods, trade secrets, and individual artistry. As far as their artistic features go, science can do little or nothing for them, but in all other ways it can be of great advantage to them.

In sharp contrast to the painfully slow development of these ancient industries is the extraordinarily swift development of such exclusively modern industries as those of synthetic dyes and others entirely based on the discoveries of modern science. The startling success and speed of growth of these are almost entirely the fruit of highly organized scientific research, with methods of scientific control at a young stage of the operations. A famous English scientist is authority for the statement that the capital, large as it has been, which the German dye firms have invested in scientific research has been the best paying investment which the world has ever seen. It is certain that an organized effort to develop the fundamental science of ceramics can have a great influence in advancing the industry.

Coming Meeting of the American Ceramic Society at Philadelphia

Headquarters for the American Ceramic Society meeting, Feb. 23-26, 1920, will be the Bellevue-Stratford Hotel, where rooms are available for general and special meetings, and where social functions will be held. Members of the society are asked to make reservations early, as all hotels in Philadelphia are crowded during the winter months.

Frederick Stanger, manager of the Enterprise White Clay Co., is general chairman of the local committee. Sub-committees have been appointed to assist him. William E. Saunders, of the United Gas Improvement Co., is chairman of the committee on the banquet. W. H. Fulweiler, of the same company, has charge of arrangements for a smoker, or "Section Q." C. H. Applegate, Jr., of the Philadelphia Textile Machinery Co., is chairman of the committee on hotel reservations. C. A. Hall, of the Pennsylvania Salt Manufacturing Co., is making arrangements for the meetings, equipment, etc. George Pettinos, of Pettinos Bros., has charge of the information bureau, and John T. Goheen, of the Brown Instrument Co., is arranging for trips of interest to be taken after the close of the meeting.

A. I. M. E. Annual Meeting

The annual convention and business meeting of the American Institute of Mining and Metallurgical Engineers will be held at the Engineering Societies Building in New York, Feb. 16-19.

Industrial excursions will be made on Thursday, Feb. 19, probably to iron and zinc mines and zinc and steel plants in the vicinity of New York, although it has been impossible to decide definitely this far in advance. In connection with the very important oil sessions, a trip is projected to one or more of the refineries in the metropolitan district.

The tentative program for the technical sessions includes the following papers:

A Foreign Oil Supply for the United States, by George Otis Smith.

Petroleum in the Philippines, by W. D. Smith.

International Aspects of the Petroleum Industry, by Van H. Manning.

Composition of Petroleum and Its Relation to Industrial Use, by C. F. Mabery.

Geologic Distillation of Petroleum, by Baily Willis.

Low-Temperature Carbonization of Coal, by S. W. Parr and T. E. Layng.

Examination of Ores and Metals in Polarized Light, by F. E. Wright.

Reverberatory Furnace for Treating Converter Slag at Anaconda, by Frederick Laist and H. J. Maguire.

Coal-pulverizing Plant, Nevada Consolidated Copper Smelter, by R. E. H. Pomeroy.

Milling Plant of the Alaska Castineau Mining Co., by E. V. Daveler.

Intercrystalline Brittleness of Lead, by H. S. Rawdon.

A Peculiar Type of Intercrystalline Brittleness of Copper, by Henry S. Rawdon and S. C. Langdon.

Relationship of Physical and Chemical Properties in Copper, by Frank L. Antisell.

Blast-furnace Flue Dust, by R. W. H. Atcherson.

Manufacture of Semi-steel for Shells, by Frank E. Hall.

An Experiment in One-piece Gun Construction, by P. W. Bridgman.

Tensile Properties of Boiler Plate at Elevated Temperatures, by H. J. French.

Microstructure of Iron and Mild Steel at High Temperatures, by H. S. Rawdon and Howard Scott.

Physical Changes in Iron and Steel Below the Thermal Critical Range, by Zay Jeffries.

Graphitization of White Cast Iron, by R. S. Archer.

Use of Microscope in Malleable Iron Industry, by Enrique Touceda.

The Coefficient of Expansion of Alloy Steels, by John A. Mathews.

Critical Ranges of Some Commercial Nickel Steels, by Howard Scott.

Forgeability of Iron-Nickel Alloys, by T. D. Yensen.

An invitation has been extended to the members of the Canadian Mining Institute to attend this meeting. A joint meeting with the Electrical Engineers for one day of the session is also being arranged.

Some Chemical Data on Coal Pyrite

A Study of the Use of Coal Pyrite for the Manufacture of Sulphuric Acid—Analyses of Coal Pyrite Samples for Sulphur, Carbon, Arsenic, Phosphorus—Summary and Conclusions

BY H. F. YANCEY*
Assistant Chemist, Bureau of Mines

IN 1917 one-third of the sulphuric acid produced in the United States was made from native sulphur.[1] This represents an abnormal condition in the sulphuric acid industry, because under normal conditions in the past very little native sulphur was used in the manufacture of acid. In 1918, however, owing to the heavy war demands the quantity of native sulphur so used increased greatly over the 1917 consumption. Conditions which necessitated curtailment of the importation of Spanish pyrite ore, and the increased demand, imposed rather critical difficulties on the acid industry. Many manufacturers began burning sulphur instead of pyrite. Under normal conditions such a procedure appears to be bad economic practice and a wasteful use of natural resources. The shortage of pyrite ore gave impetus to various Federal and State governmental agencies to locate adequate sources and deposits of this ore, and to stimulate development of known existing domestic sources.

In April, 1918, a conference of representatives of State Geologists and of the U. S. Bureau of Mines was held at Urbana, Illinois, for the purpose of investigating the possibility of the recovery of pyrite resulting from coal mining operations. The following States were represented: Iowa, Missouri, Illinois, Michigan, Indiana, Kentucky, Tennessee, Ohio, and Pennsylvania. H. A. Buehler and E. A. Holbrook represented the U. S. Bureau of Mines.

The plan adopted at this conference was to make a pyrite survey in each State. Representatives of the respective State Geological Surveys visited coal mines and estimated the possible pyrite production. In many of the mines representative samples of the pyrite or marcasite were taken, and sent to the Middle West Station of the Bureau of Mines at Urbana, Illinois, for determination of their sulphur content. As very little pyrite containing less than 35 per cent sulphur is used in acid manufacture, the determination of sulphur was considered an important adjunct of the survey work. There has not been at any previous time such a systematic investigation of production, and of sulphur content of coal-pyrite ore in the main coal-producing States. The survey indicated that about 1,500,000 short tons of pyrite concentrates could be recovered from coal-mining operations in the Eastern and Central coal fields of the United States.

SULPHUR MINERALS IN COAL MEASURES

The chief sulphur mineral occurring in coal measures is known as iron pyrites, pyrite, or ferric sulphide (FeS_2). Another mineral, known as marcasite, occurs in the coal along with pyrite. As marcasite does not differ in chemical composition from pyrite, it will be included under the general term pyrite in this report. Pyrite from coal mines is sometimes commercially termed "coal brasses" and is called "sulphur" by the miners; other local names sometimes used for coal pyrite are "sulphur balls," "kidney sulphur," "cat faces," and "niggerheads." A "niggerhead" may or may not be pyrite. Some of them consist almost entirely of calcium carbonate, while others are completely pyritized. The mineral pyrite occurs as bands, lenses, nodules, and in very thin leaves in the coal seam. The thin leaves occurring in the cleavage planes are not recoverable, and are therefore not within the scope of this discussion.

Fig. 1 shows a typical pyrite lens with adhering coal. The lens represents a fair grade of pyrite, though streaks of foreign carbonaceous material may be noted in it. Fig. 2 is a view of a typical band of high-grade pyrite adhering to the coal. This particular band was almost continuous and occurred near the top of the coal seam. The lenticular and band pyrite are very rarely so interbedded or intergrown with coal or slate as to be of low grade when freed of outside adhering coal. The figures give an idea of the approximate size of both the lens and band pyrite. These two forms of pyrite are the most important from the standpoint of sulphur recovery in most of the mines. Fig. 3 shows two views of a pyrite nodule, boulder or "niggerhead." The adhering coal has been mostly removed. The upper picture shows a top view of the elipsoid-shaped nodule. The lower picture represents the cross-section, the nodule having been broken with the hammer. The nodule has been completely pyritized. Some of these nodules occurring with the coal have not been completely pyritized, and have only a thin outer layer of pyrite surrounding the limestone center. This form of pyrite is therefore not so important as band and lenticular pyrite.

EXPERIMENTAL WORK ON COAL PYRITES

In this paper the results of sulphur determinations on about 120 samples of pyrite from nine States are recorded. Most of the samples were from Ohio and Missouri. Other samples were from Indiana, Tennessee, Kansas, Kentucky, Illinois, Pennsylvania, and Michigan. About 250 samples of milling products resulting from the concentration of picking belt refuse, washery refuse, and handpicked coal-pyrite ore were analyzed for sulphur. Specific gravity determinations on coal-pyrite containing varying amounts of sulphur are given. The relation of color and sulphur content is discussed. Brief reference is made to impurities occurring with some pyrite ore which rendered difficult ore-dressing operations designed to produce a

*By permission of the Director, U. S. Bureau of Mines.
[1] U. S. Geol. Survey, Mineral Resources, part 2, p. 61; 1917.

high-grade commercial pyrite concentrate. The carbon and arsenic content of pyrite concentrates is recorded because of its bearing on the manufacture of sulphuric acid from such concentrates. The percentage of phosphorus in pyrite from coal mines is given, for a few samples, because of the importance of investigating possible sources of low-phosphorus iron ore.

The results of numerous ore-dressing tests on coal-pyrite ore will be given in a separate Bureau of Mines publication.

Preparation of Samples for Analysis

The samples received from the field were first cleaned to remove adhering slate and coal particles from the pyrite. This was done because the information desired was the sulphur content of the mineral itself, and not of the mineral and its adhering impurities. It is obvious that a milling operation designed to produce pyrite concentrates would involve

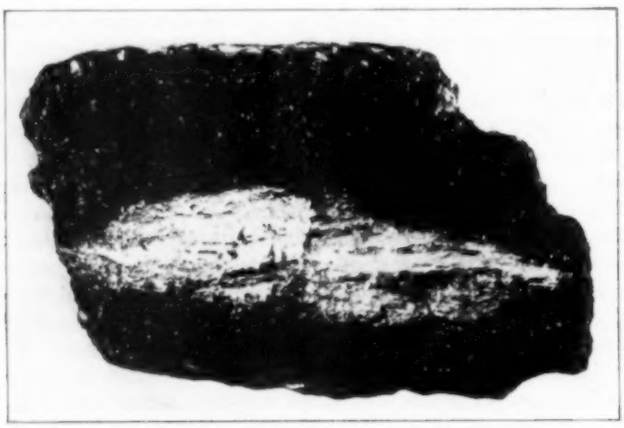


FIG. 1. LENS OF PYRITE (ABOUT ONE-THIRD ACTUAL SIZE)

crushing and washing of the ore so as to remove adhering slate and coal. After the samples were cleaned a brief description of the physical appearance was recorded, and an estimate of the sulphur content of the cleaned mineral was made.

Determination of Sulphur by the Parr Method

The sulphur was determined according to the method of S. W. Parr.[3] One-half gram of the sample, crushed to pass 80 mesh, was weighed into a Parr sulphur bomb and intimately mixed with about 7 to 10 grams of sodium peroxide. About one-half gram of potassium chlorate was then added, and an equal amount of powdered benzoic acid. The lid was then secured on the bomb, and the contents mixed by shaking vigorously. The bomb was next heated over the Meker burner for five minutes; the explosion generally occurred about one-half minute after the bomb was placed over the flame. The heating was continued because the explosion itself does not always give a perfect fusion resulting in the decomposition of all of the pyrite. At the end of five minutes the bomb was cooled under the water-tap, the lid removed, and the fusion crucible placed in a beaker containing about 100 cc. of water. When the reaction had subsided the crucible was washed out, the solution neutralized with hydrochloric acid, and 4 cc. added in excess. The solution was then filtered, diluted to about 300 cc., and the sulphate precipitated from the hot filtrate by the addition of an excess of 10 per cent of barium chloride solution according to the standard method. After standing, the precipitated barium sulphate was removed by filtration, and washed with dilute hydrochloride acid (5 cc. concentrated hydrochloric acid in one liter of hot water). This is followed by several washings with hot water. The precipitate was then ignited at a dull red heat, cooled and weighed.

Other Methods for the Determination of Sulphur

The method described is sufficiently accurate for this study, and more rapid than most of those involving wet oxidation of pyrite. Some investigators have pointed out that barium sulphate should be precipitated from cold[3] solutions containing ferrous,[4] rather than ferric, iron.

These refinements increase the time required for the determination, and were not used because a high degree of accuracy was not required. However, for extremely accurate work on high sulphur materials, such as pyrite, it is probable that the method of Allen and Bishop[4] would be more satisfactory for umpire and sulphuric acid company analyses.[5] They obtain slightly higher results in the absence of alkali chlorides. Allen and Bishop's method requires the reduction of the iron in the solution before the precipitation of barium sulphate; while Smoot[6] advises the removal of this iron, before precipitation of the sulphates, by electrolysis, using a mercury cathode. Allen and Johnston[7] have referred to the disturbing influence of alkali chlorides, and recommend the Carius method of oxidation by heating with fuming nitric acid in a sealed tube. Hulett and Dushak[8] have investigated this subject. The method of Lunge[9] is widely used both in this country and abroad.

Comparative Study of Sulphur Determination Methods

A comparative study of the different methods was made by the joint committee on standard methods for coal analysis, with a very satisfactory showing for the sodium peroxide fusion procedure.[10] References to some of the recent work on the determination of sulphur are given below.[11]

The Parr method was found to be quite satisfactory for all milling products resulting in the concentration of coal-pyrite ore. Some of these products carried considerable amounts of slate and clay, and therefore of silica. This silicic acid did not separate, at the dilution mentioned, when the sodium peroxide fusion was acidified with hydrochloric acid, and even when present in the sample to the extent of 65 per cent did

[3]Parr, S. W., "The Use of Sodium Peroxide in Certain Quantitative Processes," *J. Am. Chem. Soc.*, vol. 30, p. 764; 1918. "A Fusion Bomb for Sulphur Determination in Coal," *J. Ind. Eng. Chem.*, vol. 11, p. 230; 1919.

[4]Folin, Otto, *J. Biol. Chem.*, vol. 1, p. 131; 1905-06.

[4]Allen, W. S., and Bishop, H. B., Eighth International Cong. App. Chem., vol. 1, p. 33; 1912.

[5]Moore, H. C., *J. Ind. Eng. Chem.*, vol. 7, p. 634; 1915; *Ibid.*, vol. 8, p. 1167; 1916. *Ibid.*, vol. 11, p. 45; 1919.

[6]Smoot, A. M., *Eng. Mining J.*, vol. 94, p. 412.

[7]Allen, E. T., and Johnston, J., *J. Am. Chem. Soc.*, vol. 32, p. 588; 1910.

[8]Hulett, G. A., and Dushak, L. A., *Zeit. anorg. Chem.*, vol. 40, p. 196; 1904.

[9]Sulphuric Acid and Alkali, vol. 1, part 1, p. 95.

[10]*J. Ind. Eng. Chem.*, vol. 5, p. 525; 1913.

[11]Raeder, M., *Tid. Kemi Farm. Terapi*, vol. 14, p. 257; 1917. *Chem. Abs.*, vol. 12, p. 1160; 1918. Martin, E., *Mon. sci.*, vol. 8, p. 149; 1918. Karaoglanow, Z., *Zeit. anal. Chem.*, vol. 56, p. 561; 1917. *Ibid.*, vol. 57, p. 77; 1918.

not contaminate the barium sulphate precipitate.[12] This was determined by evaporating one sample containing 65 per cent silica to dryness, after the water leach of the sodium peroxide fusion had been acidified with hydrochloric acid. The resulting dehydrated silica was then filtered off, and the sulphates precipitated. Several determinations gave a value agreeing very closely with that obtained by precipitating the sulphates directly without previous removal of the silica. This particular sample contained 15 per cent sulphur.

Sulphur Content of Specimens

Ohio.—The State of Ohio was represented by 47 samples. Pyrite investigations were made in about 150 mines. Of the 47 samples examined only 24 per cent contained less than 40 per cent sulphur. Only 4 per cent of the samples contained less than 35 per cent sulphur. The best sample had a sulphur content of 51.2 per cent. The formula FeS_2 requires 53.42 per cent sulphur and 46.58 per cent iron. This sample had the highest percentage of sulphur of any examined during the entire investigation. Mr. W. M. Tucker conducted the investigation in Ohio.

Missouri.—Thirty-six samples of pyrite were collected in thirty-four Missouri coal mines by Mr. Russell Gibson of the Missouri Bureau of Mines and Geology. Twenty-two per cent of the samples examined contained less than 40 per cent sulphur, while only 5 per cent of the samples contained less than 35 per cent sulphur. The best sample showed 48.5 per cent sulphur.

Indiana.—Only one sample of pyrite from Indiana was examined. This contained 46 per cent sulphur. Four samples of concentrates obtained in washing Indiana coal-pyrite ore were found to contain from 44 to 46 per cent sulphur. A report on pyrite in Indiana coal has been prepared by Mr. L. P. Dove and will be published by the Indiana Geological Survey.

Tennessee.—Five samples came from coal mines in Tennessee. All of these samples contained more than 45 per cent sulphur. The specimen having the highest sulphur content analyzed 47.6 per cent. Three lots of hand-picked ore from this State gave high-grade sulphur concentrates with good recoveries of sulphur. In two of these lots the heads contained 40 per cent sulphur.

Kansas.—No samples were collected in Kansas, but one lot of hand-picked coal-pyrite ore was received and concentrated. The head sample of this lot showed 40.3 per cent sulphur. The concentrates obtained by crushing and washing contained 46.5 per cent sulphur.

Kentucky.—Three samples were collected in Kentucky. All three samples contained more than 43 per cent sulphur, 45.6 per cent being the highest. Two samples of washery refuse from a different part of the State were not amenable to concentration, because siderite with some calcium carbonate occurs as a stony impurity along with the pyrite. The siderite and pyrite are closely intermixed, as rather fine crushing, prior to washing, was necessary to give a satisfactory concentrate. The specific gravity of this siderite, being 3.2, rendered the washing and concentration of the ore difficult.

Illinois.—Seventeen pyrite samples were submitted by the Illinois Geological Survey. All but three of these samples contained more than 40 per cent sulphur. The best sample contained 48.9 per cent sulphur. Mr. G. H. Cady made the pyrite survey in Illinois, and the results of his investigation will appear as a bulletin of the Illinois Geological Survey Division. Among the States Illinois ranked third in the production of pyrite in 1917.[13] It is significant that all of this pyrite was recovered in coal-mining operations. Two important papers dealing with this subject have been published.[14]

FIG. 2. BAND OF PYRITE (ABOUT ONE-THIRD ACTUAL SIZE)

Pennsylvania.—Two samples of pyrite were received from the Topographic and Geologic Survey Commission of Pennsylvania. They both contained about 44 per cent sulphur. Two samples of washery refuse were examined, both of which contained about 20 per cent sulphur, but which would produce a high-grade pyrite by concentration. Two lots of coal-pyrite ore gave high-grade concentrates with satisfactory recoveries of sulphur on washing.

Michigan.—The coal mines of Michigan were represented by three samples. A washery refuse concentrate contained 41 per cent sulphur. Two samples of pyrite showed 47.2 and 38.5 per cent sulphur. The high-grade sample was dark in color, but dense, heavy and amorphous, while the low-grade (38.5 per cent) sample was brass-yellow, crystalline and much lighter, indicating a lower specific gravity.

TABLE I. SULPHUR CONTENT OF COAL PYRITE

State	Number of Samples Examined	Per Cent of Samples Containing Over 40 Per Cent Sulphur
Ohio	47	75
Missouri	36	78
Indiana	5	100
Tennessee	5	100
Kentucky	3	100
Illinois	17	93
Pennsylvania	2	100
Michigan	3	66
Kansas	1	100

The summory of the sulphur content of specimens is given in Table I.

Relation of Appearance to Sulphur Content

The mineral pyrite generally occurs as brass-yellow cubic or other isometric crystals. Marcasite differs from pyrite in crystalline form only in that it is generally lighter in color, and has a slightly lower specific gravity.

As has been previously mentioned, a record was made of the physical appearance of the sample. By comparison of this record with the sulphur content

[12] Hillebrand, W. F., U. S. Geol. Sur., Bull. 422, pp. 196-198; 1910.

[13] U. S. Geol. Survey, Mineral Resources, part II, 26; 1917.

[14] Holbrook, E. A., "The Utilization of Pyrite Occurring in Illinois Bituminous Coal," Illinois Univer. Engineering Exper. Sta., Aug. 20, 1917. Pogue, J. E., "The Pyrite Situation With Special Reference to Coal Mining in Illinois," 4 pp., Illinois Geological Survey, October, 1917.

it was early found that the color of the specimen did not give an accurate indication of probable purity. In fact many of the coal-pyrite specimens containing more than 45 per cent sulphur were dirty-gray or brown in color, dull and non-crystalline even on fresh fracture. Samples of bright brass-yellow crystals of pyrite from Virginia and Georgia pyrite mines (not coal mines) were often found to contain less sulphur than dull, dirty-gray specimens of pyrite from coal. In several instances samples of pyrite from coal, having a brass-yellow, crystalline appearance, were found to be rather low in sulphur.

In a general way it was found that the estimation of the grade of a coal-pyrite specimen (sulphur content) should be based upon its apparent specific gravity when "weighed" in the hand, rather than upon its color or structure.

The specific gravity of pure pyrite is given by Dana[32] as 4.95 to 5.10, and by Moses and Parsons[33] 4.9 to 5.2. The same authorities give the specific gravity of marcasite as 4.85 to 4.90 and 4.6 to 4.9 respectively. The specific gravity of several samples of pyrite from coal mines is given in Table II. The corresponding sulphur determination was made on a portion of pyrite from the same piece as that used for the specific gravity determination, except in the case of the sample from Ohio, when both determinations were made upon the finely pulverized sample.

TABLE II. SPECIFIC GRAVITY OF COAL-PYRITE

Lab. No.	Per Cent Sulphur	Specific Gravity
Tenn. 11	15.1	2.70
Ill. 18	25.5	2.89
Ill. C-17-51	29.7	3.62
Ill. C-18-20	42.0	3.99
Ill. C-18-62	44.0	4.41
Ill. 22	46.7	4.09
Ill. C-18-68	48.9	4.32
Ohio 111A	51.2	4.76

It will be noted that sample 111A from an Ohio mine contained nearly the theoretical (53.42) per cent of sulphur, and showed the highest specific gravity. This is to be expected. Even this sample has a specific gravity too low to meet Dana's value for either pyrite or marcasite, but does come within the limits given for marcasite by Moses and Parsons. As shown in the table the specific gravity of pyrite does not increase directly with the sulphur content. It is apparent that variations in the specific gravity of the non-pyritic material would account for these variations.

Carbon in Coal-Pyrite Concentrates

It is generally assumed that carbon dioxide exercises an injurious action in the lead chambers, and for this reason "coal-brasses" have not been considered good raw material for the manufacture of sulphuric acid until quite recently. It now seems that this assumed injurious action was due to inaccurate information, or to difficulties encountered in making sulphuric acid from roughly hand-cleaned coal-pyrite ore containing from 10 to 25 per cent coal with its accompanying volatile matter. The maximum amount of carbon in pyrite concentrates allowed without penalty is generally 8 per cent. Lunge[34] states that a Bohemian works is making sulphuric acid from a material containing 10 per cent bituminous material without any special trouble. Pyrite concentrates from a pyrite washery contain much smaller amounts of carbon, and apparently do not cause trouble in the manufacture of acid. Some figures on the carbon content of pyrite concentrates are given in Table III.

TABLE III. CARBON CONTENT IN COAL-PYRITE CONCENTRATES

Product	Total Sulphur Per Cent	Total Carbon Per Cent	Organic Carbon Per Cent
First Bed Pyrite Concentrates	44.77	2.90	2.27
Pyrite Lump Concentrates	45.88	2.60	1.83
First Hatch Pyrite Concentrates	45.03	3.75	2.96
Recleaned Pyrite Middlings	43.88	6.76	6.61

Analyses made at the Pittsburgh Station, Bureau of Mines.

In this connection Parish[35] has called attention to some of the difficulties met in the manufacture of sulphuric acid from coal-pyrite. He states that coal-brasses should contain a minimum of 38 per cent available sulphur, and ferrous sulphate not to exceed

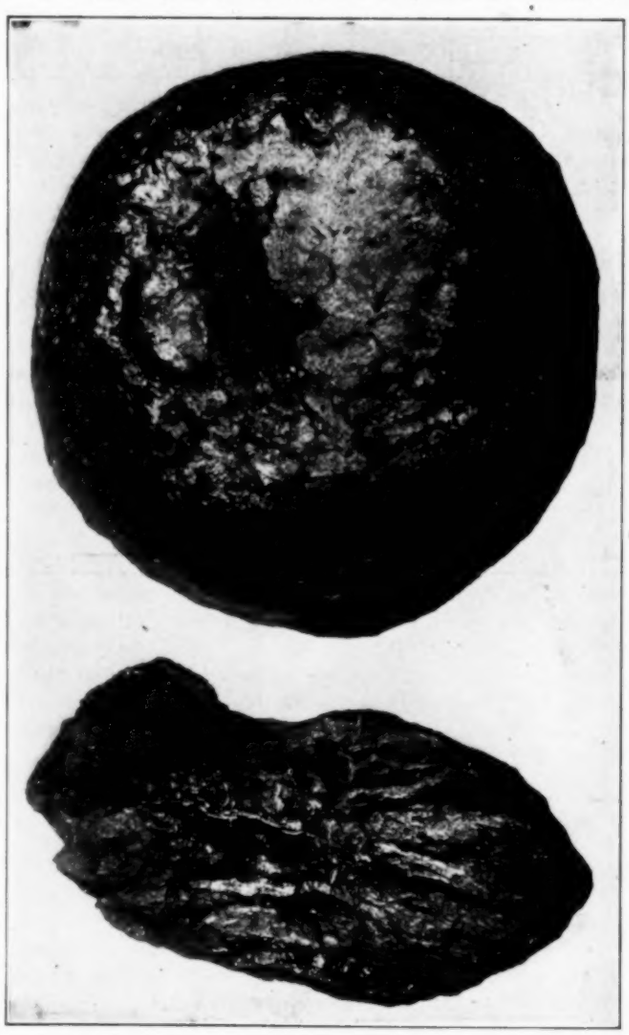


FIG. 3. BALL OF PYRITE (ABOUT ONE-THIRD ACTUAL SIZE)

6 per cent. He recommends the use of a nitric acid feed on the Glover tower, and points out that carbon dioxide occupies valuable chamber space in the system. Excessive amounts of iron sulphate would not

[32]Textbook of Mineralogy, 1913.

[33]Mineralogy, Crystallography and Blowpipe Analysis, 1900.

[34]Lunge, G., Sulphuric Acid and Alkali, vol. 1, pt. 2, p. 971; 1913.

[35]Parish, P., *Gas J.*, vol. 141, p. 246; 1918.

be present in a freshly prepared pyrite concentrate. Thereafter, the amount present would depend upon the conditions of and the length of time in storage, as well as upon the mineralogical and physical characteristics of the pyrite. Experience seems to indicate that under average conditions the formation of iron sulphate would not materially affect the value of coal-pyrite concentrates, but storage for more than a year might be inadvisable.

In connection with storage, the tendency of coal pyrite to fire spontaneously must be considered. It is well known that hand-picked pyrite, containing, as it does, generous amounts of coal, takes fire quite readily during storage. Information covering the storage of washed pyrite concentrates, which ordinarily contain less than 5 per cent of carbon, for long periods of time are not available. However, pyrite washeries in Illinois have never experienced appreciable heating or firing of washed concentrates during storage for several months.

Arsenic in Coal Pyrites

Arsenic is poisonous, and has an especially injurious effect on the production of sulphuric acid by the contact process. According to Hjelt[19] Spanish pyrite from the Rio Tinto district contains an average of 0.91 per cent arsenic. Pyrite recovered from coal-mining operations showed much less of arsenic in six samples examined. A sample from Pennsylvania supposed to be high in arsenic contained 0.056 per cent. A sample of concentrates from an Illinois pyrite washery having an output of 1700 tons of pyrite concentrates per month showed only 0.029 per cent of arsenic. Another Illinois pyrite washery concentrate contained only 0.005 per cent. The first hutch product obtained in jigging several hundred pounds of Ohio coal-pyrite ore contained 0.005 per cent arsenic. A similar product, but from Tennessee, had an arsenic content of 0.015 per cent. A jig concentrate on Pennsylvania ore contained 0.039 per cent arsenic. The results on these samples can be taken as fairly representative of coal-pyrite concentrates, and show that the arsenic content of this material is negligible.

Phosphorus in Coal Pyrite

The clinker or cinder remaining after burning off the sulphur from pyrite has been utilized as an iron ore. The material is generally so fine that it requires agglomeration or nodulizing, as well as roasting, to remove the remaining sulphur. Several other factors determine its suitability for use as an ore of iron, but because of the present low-phosphorus iron-ore situation, it was considered advisable to determine the amount of phosphorus present in coal-pyrite. Ten samples of pyrite concentrates were obtained at pyrite washeries and from milling tests on half-ton lots of coal-pyrite ore. The percentage of phosphorus found to be present in the pyrite varied from 0.003 to 0.083 in these concentrates. Seven of the samples contained less than 0.015 per cent phosphorus, while four showed less than 0.008 per cent phosphorus. It is apparent that a considerable portion of the burnt coal-pyrite cinder could be used for the production of low-phosphorus iron. In England the cinder is used in the manufacture of paint.[20]

[19] Hjelt, *Dingler's polytech. J.*, vol. 226, p. 174.
[20] Parish, P., *Gas J.*, vol. 141, p. 246: 1918.

Summary and Conclusions

Most of the pyrite occurring with coal contains economic and useful percentages of sulphur.

Color and physical appearance do not indicate probable sulphur content.

Properly prepared pyrite concentrates do not contain injurious amounts of carbon.

Pyrite from coal contains only very small amounts of arsenic.

Pyrite from coal is mostly low in phosphorus.

Acknowledgment

The work described in this paper was carried out under the direction of E. A. Holbrook, to whom acknowledgment is made.

This report was prepared under a co-operative agreement among the Illinois State Geological Survey Division, the Engineering Experiment Station of the University of Illinois, and the U. S. Bureau of Mines. The work was conducted in the Mining Laboratory of the University of Illinois.

U. S. Bureau of Mines,
Urbana, Illinois.

Furnace for Testing Firebrick Under Load at High Temperatures

By C. H. Lovejoy

THE proposed standard test for firebrick under load at high temperatures, outlined in the 1918 *Proceedings* of the American Society for Testing Materials, and more extensively described in this journal of date Jan. 1, 1918,[1] leads me to write this description of a furnace for similar purpose, which has been used by the Pittsburgh Testing Laboratory, Pittsburgh, Pa., for the past five years. The main differences between these furnaces lie in the manner of applying the load and the means of determining the load at any time during the progressive failure of the brick under test.

The apparatus consists essentially of a firebrick chamber in which the test brick is heated while a pressure is applied at the ends. We use a pressure of 50 lb. per sq.in. (double that recommended), which will produce ultimate failure in all but the best brick when the temperatures mentioned in the proposed test are attained. By applying the load with a spring instead of levers, we are able to carry practically all our tests to ultimate failure, determine the variation in load sustained by the brick at the higher temperatures, and obtain an idea of the rate of failure. The spring we use is easily removed and frequently checked up in our testing machine. This is mostly a matter of form, for when in use it is never stressed to capacity, and we have found no appreciable differences in it during the five years it has been in service. When compiling our results we plot a load-temperature curve as well as a time-temperature curve. As a rule we try to have our time-temperature curves alike and draw our conclusions from the load-temperature curve.

The apparatus is best described by outlining the procedure followed in making a test. The brick to be tested, *T*, is placed in the center of the furnace (Fig. 1); the upper end blocked to the roof with half of a refractory brick, the lower end blocked to the moving piston, *P*,

[1] "A Furnace for Testing Refractory Materials Under Load at High Temperatures," Robert J. Montgomery. Met. & Chem. Eng., vol. 18, No. 1, p. 18, Jan. 1, 1918.

with another refractory brick. To guard against eccentricity in loading, a very thin piece of sheet asbestos is placed between the blocks. The opening in the bottom of the furnace is closed by a piece of heavy asbestos board fitted around the lower blocking brick.

The piston *P* is raised by turning nut *N* until the brick to be tested and the blocking are in firm contact with each other. The length of the uncompressed spring is now measured accurately. Further turning of nut *N* will produce compression in the spring and bring pressure to bear on the end of our test brick. For each inch of compression in the spring we use, we obtain 400 lb. load. Suppose the end area of our brick to be 2¼ in. x 4¼ in. = 9.56 sq.in. at 50 lb. per sq.in. = 478 lb. total load to be applied. This will be obtained by continuing to turn nut *N* until the spring is compressed 478 ÷ 400 = 1.19 in.

The two gas burners at *B* and *B* (Fig. 2) are lighted, at first without any air blast. These burners are staggered so that no flame shall impinge upon the test specimen. When the furnace has reached 500 deg. C. the door *D* is blocked, the blast turned on, and regulated so as to reach 1350 deg. C. in five hours, and maintained at this temperature for one hour. Furnace temperatures are read every 20 minutes by an electric pyrometer inserted through *H*, opposite the brick. The amount of compression in the loading spring is measured at the same time. Very poor brick will start to fail and bulge in the middle as low as 950 deg. C. or 1000 deg. C., the load falling off in proportion as this deformation reduces

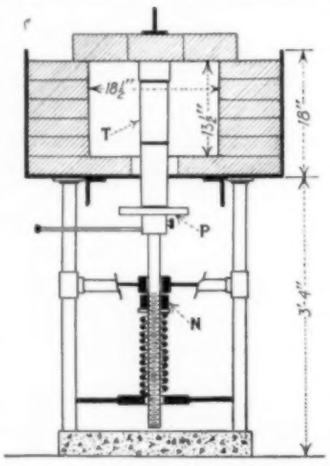


FIG. 1. SECTION THROUGH FURNACE

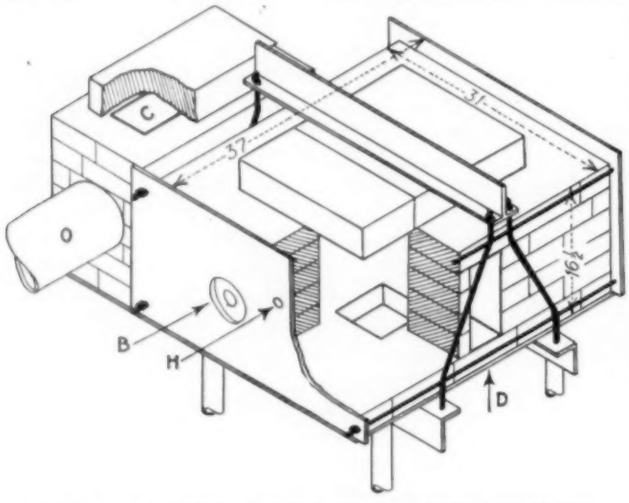


FIG. 2. ISOMETRIC VIEW OF HEATING CHAMBER

the amount of compression in the spring. Such brick will show complete failure below 1200 deg. C., the spring having returned to its original length, the load reduced to zero. This class of brick is not useful in arch construction or other work where it is necessary that the brick stand a load. Fair brick will start about 1100 deg. C. and still have about 25 lb. per sq.in. left on them at 1350 deg. C. First-class brick will generally show no signs of failure before 1200 deg. C. and many will stand 1300 deg. C. before starting to fail. We have found only two brick that would show no signs of fail-

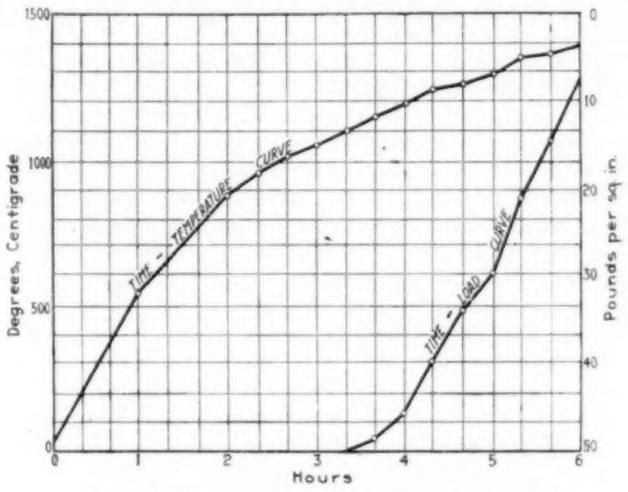


FIG. 3. TEST OF FAIR QUALITY FIREBRICK

ure at 1350 deg. C. If desired the temperatures may be carried above 1350 deg. C. to whatever point is necessary to produce complete failure; always at temperatures below 1500 deg. C.

Considerable difficulty was experienced with the original furnace through the frequent melting off of the outlet pipe carrying away the gases, until the extra chamber *C* was built on the rear of the furnace.

In the proposed standard test using the lever furnace, the load remains constant, and different rates of heating are recommended for different qualities of brick, always stopping short of ultimate failure. In our work we receive samples from many sources in which the main question is not what this specimen will stand without failing but what this brick is good for and where it will fail. Our furnace enables us to arrive more quickly at the answer to this question.

For general testing and variety of service we have found this furnace very satisfactory. The metal work is simple and easy to assemble; the spring insures straight line application of the load; the brick work is made without special shapes and is easily laid up; and the whole furnace is compact and was moved twice in the last year with a minimum of effort.

The credit for the general design of this furnace belongs to J. B. Shaw, who built the original furnace. Several attachments have been added by other members of our staff for the purpose of making it automatic and self-recording, but it is not essential to describe them here.

Pittsburgh Testing Laboratory,
Pittsburgh, Pa.

Extension of General Import License

The general import license has been extended to cover salvarsan, neo salvarsan, arsphenamine, and all substitutes and equivalents therefor, and narcotics. The effective date was Jan. 10. Individual import licenses therefore will not be required for these commodities except when shipments originate in that part of Russia under control of the bolshevik authorities.

Reminiscences of Early Years at the Great Falls Smelter

Brief Notes of the Early Development of this Once Great Copper Concentrator and Smelter, Particularly as Affected by the March of Events in the Metal and Share Market Ore Supply and Metallurgical Science

BY CHARLES H. REPATH

Consulting Engineer,
Sometime Chief Engineer, Boston & Montana C. C. & S. M. Co.

AFTER operating for more than 20 years, the concentrator at Great Falls, Montana, was closed down somewhat before the outbreak of the war. It was maintained in operating order, however, for many months, but finally the machinery was removed, scrapped or disposed of as opportunity offered.

The definite passing of this mill—perhaps the oldest in the Rocky Mountain copper regions—where were solved many of the problems underlying the mammoth operations of today, warrants more than perfunctory mention. In fact, during the '90s the plant was known as the "last word" in copper, its pre-eminence falling only with the completion of the large Washoe works in Anaconda. Even thereafter, the staff was continually working on the betterment of the milling and smelting practice, and was able to make refinements in principle and method which have been of wide application elsewhere. Possibly, then, these reminiscences of early years at this plant may be of more than casual interest.

The Boston & Montana Consolidated Copper & Silver Mining Co.—or more briefly, as it is still known, the "B. & M."—was organized with a moderate capitalization late in the '80s, and owned some Butte mining properties on the northeasterly end of the then productive copper zone. It also owned two small plants near by in Meaderville—the upper works, and the Colusa, or lower works, one of which embodied, by the way, the first copper concentrator started in Butte, a 25-ton mill erected in 1881 by A. Wartenweiler for the Montana Copper Co. to produce jig concentrates of copper glance from Colusa ore. The early B. & M. operations were quite profitable, and in 1889, when it was decided to increase the smelting capacity, the first steps were taken by the management in the issuance of a $500,000 bond issue to cover construction. At that time the output was a high-grade matte which was shipped to England for refining—the monthly production contained about 2,000,000 lb. of copper and 14,000 oz. of silver.

A NEW SMELTER AUTHORIZED

It was not easy to determine the correct location for what was then thought to be a large smelter. Available sites in Butte were cramped, water was scarce, coal and coke expensive, and the existing sulphur smoke unendurable. A much more favorable area was purchased in Cascade county, on the north bank of the Missouri River, just below Black Eagle, the first of a series of wonderful waterfalls which have but recently been utilized. Here was available power to drive machinery and pumps, ample water for concentration, and a big river into which tailings and slag could be sluiced. At Belt or Sand Coulee, within a few miles, was located extensive deposits of bituminous coal, already developed and supplying locomotive fuel at about $1.75 per ton. Unfortunately, however, the site was 175 miles from the mines across the continental divide, and the question whether ore should be hauled to the coal or coal to the ore was argued at length. A favorable freight rate (65c. per ton) was negotiated, however, and tentative plans were adopted for a 2-section 500-ton concentrator, Brückner roasters, producers for gasifying the bituminous coal and tilting open-hearth smelting furnaces.

Mr. Charles O. Parsons, the general manager at that time, employed Mr. Frank Rossberg, a concentrator man from Anaconda, to design the mill. The first question was the method of crushing to be employed—whether to use the steam stamps so successful in the Michigan copper country or the jaw crushers and rolls thought to be more applicable in Butte. Montana milling practice had been strongly influenced by Michigan ideas at a somewhat earlier date, when Marcus Daly went to the Calumet & Hecla to get a man to design a new mill at Anaconda, fortunately securing the services of Otto Stahlman, then working as draftsman under John Ellenbecker. Daly was much impressed with the magnitude of the operations in Michigan, and while the old mills at Anaconda had already demonstrated the efficiency of crushers and rolls, they were rather small installations and Daly threw aside all their accumulated experience for the "bigness" of a stamp mill. Rossberg, although originally a Michigan steam-stamp proponent, had a very open mind and knew that the stamp was far from perfect, and while the cost of stamping was much less it produced many fines, causing a tremendous loss in values. Great Falls construction was therefore delayed for months through 1890 on account of this controversy between what might be differentiated as the Anaconda system and the B. & M. system of concentration. The former, as noted, exemplified Michigan practice using steam stamps, hydraulic separators, Collom jigs, and revolving slime tables. The B. & M. Colusa mill attempted to reduce sliming by crushing in Blakes and Cornish rolls, and to cut down the water consumption by screening in trommels, then concentrating on Hartz jigs and vanners. Evidently a proper choice required the decision of fundamental questions.

CHARACTER OF SITE AT GREAT FALLS

Tentative ground plans and cross-sections were adopted, however, sufficient to allow excavation and foundation work to proceed. The site chosen was against a steep river bank, close to the falls, where power could be transmitted from the wheels by rope drives, and where the huge quantities of water required

could be readily available. How big an item the latter was can be appreciated when it is known that the 500-ton mill required 240,000 gal. of water per hr.—many times what would be used today. The excavation was enormous—a series of benches were dug into the hillside, mostly in a water-bearing shale, exceedingly tough when fresh, but rapidly disintegrating into a slippery clayey mass on exposure. Immense rock retaining walls were therefore necessary, not only to hold up the benches, but also to withstand the impact of the steam stamps, should they later be installed.

The delays due to indecision as to plans and to extra heavy work, the overrunning of estimates, and the expanding construction program caused much dissatisfaction with the Great Falls management, and called for a second bond issue of $600,000 to complete the smelter. In order to find out the exact status of affairs, the Eastern management in the spring of 1891 asked Captain Daniell and Frank Klepetko of the Tamarack Mining Co. to inspect construction operations, in company with

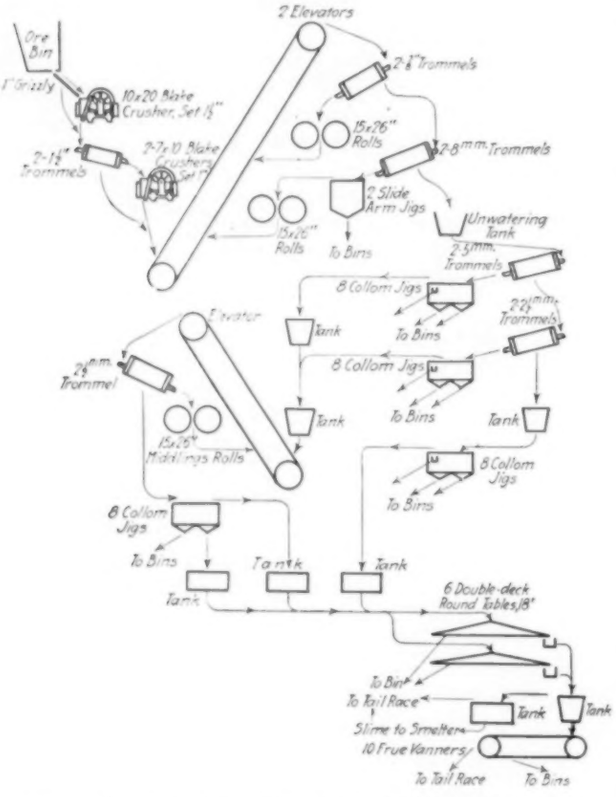


FIG. 1. ORIGINAL FLOW SHEET OF CONCENTRATOR, 1892.

Thomas Couch, Butte manager of the B. & M., and C. H. Palmer of the Butte & Boston. Their report quieted much of the official apprehension, and Mr. Klepetko was soon after retained as manager, being given instructions to push the work to completion with all possible speed. After investigating the concentrator problem, he decided against steam stamps and ordered the installation of the Butte system. This was accordingly done, and the mill started in March, 1892.

Original Mill

A brief description of the original mill follows: Concentrating machinery occupied two-thirds of a wooden building, 136 ft. by 262 ft. in dimensions. Ore was delivered to wooden storage bins of 3600 tons capacity, crushed in 10 by 20 and 7 by 10 Blake crushers and 15 by 26-in. rolls, and concentrated in slide arm jigs, Collom jigs, and double deck round tables whose tailings were finally treated on Frue vanners, all as shawn on the flow sheet (Fig. 1). This machinery was driven by two 44-in. water wheels, from which a 400-hp. manilla rope transmission went to the mill, together with a 250-hp. transmission to the smelter. A 40-in. wheel was also used in the power house to drive two rotary pumps, furnishing 3500 gal. per min. through a 24-in. riveted pipe, about 1000 ft. long. The remainder of the mill was occupied by a 22 by 48-in. Corliss engine for reserve power, and a 15 by 30-in. Ball steam stamp for reserve crushing.

Early operations in the mill were fairly satisfactory from the viewpoint of recoveries. Many troubles appeared due to disproportionate spouting and splitting of feeds, but such difficulties were encountered ten years later when the Washoe mill started. Shortly after concentration commenced, Mr. Klepetko brought Mr. W. A. Estabrook over from the B. & M. plant in Butte to be superintendent of the concentrator, Mr. Rossberg leaving to work up a centrifugal milling machine for some Helena people. Estabrook made a number of changes which, while not affecting the general flow sheet greatly, practically rebuilt the entire plant and brought the mill up to its rated capacity of from 500 to 600 tons per day. Rolls, elevator boots and heads, trommels and launders were raised or lowered for more adequate service. During all this time there was a continual struggle with poor machine design—constant and vexatious delays due to breakages in crushing, jig or table division resulted in new designs and local construction for nearly every piece of machinery in the concentrator.

Smelting Practice

Meantime the smelting departments were not having an easy time of it. These were arranged as shown in Fig. 2, housed in a light steel building 230 by 455 ft. in dimensions, built by the Berlin Iron Bridge Co. (at a cost of about $60,000, by the way!) Roasting was done in 24 Brückners, then the perfection of roasting practice, with a rated capacity of 16 tons per day; actually about 250 tons of concentrates were calcined. In the design of the metallurgical machinery, Julian Kennedy of Pittsburgh was retained as consulting engineer, and the plant showed many points of similarity to steel-works practice. Twenty-four Wellman gas producers supplied gas to eight matte furnaces (Fig. 3)—small tilting open-hearths operated with hydraulic cylinders and with regenerative checkerwork. Six of these were gas-fired, while two, owing to lack of capacity in the producers, were operated experimentally by direct coal-firing. Slag was granulated and sluiced to the Missouri River below—a most economical disposal which continued until three or four years ago. A high-grade matte was produced, crushed, sacked and shipped to New York. Later it was handled in pots by one 20-ton overhead crane to two converter stands, each designed for 5 tons of matte. (Seventeen-pound air was furnished through 1600 ft. of 30-in. riveted pipe from a blowing engine near the water wheels.) The detailed construction of these stands was very similar to those at bessemer steel plants, with sectional shells, and hydraulic operation centrally controlled from a pulpit. It was originally thought that only the

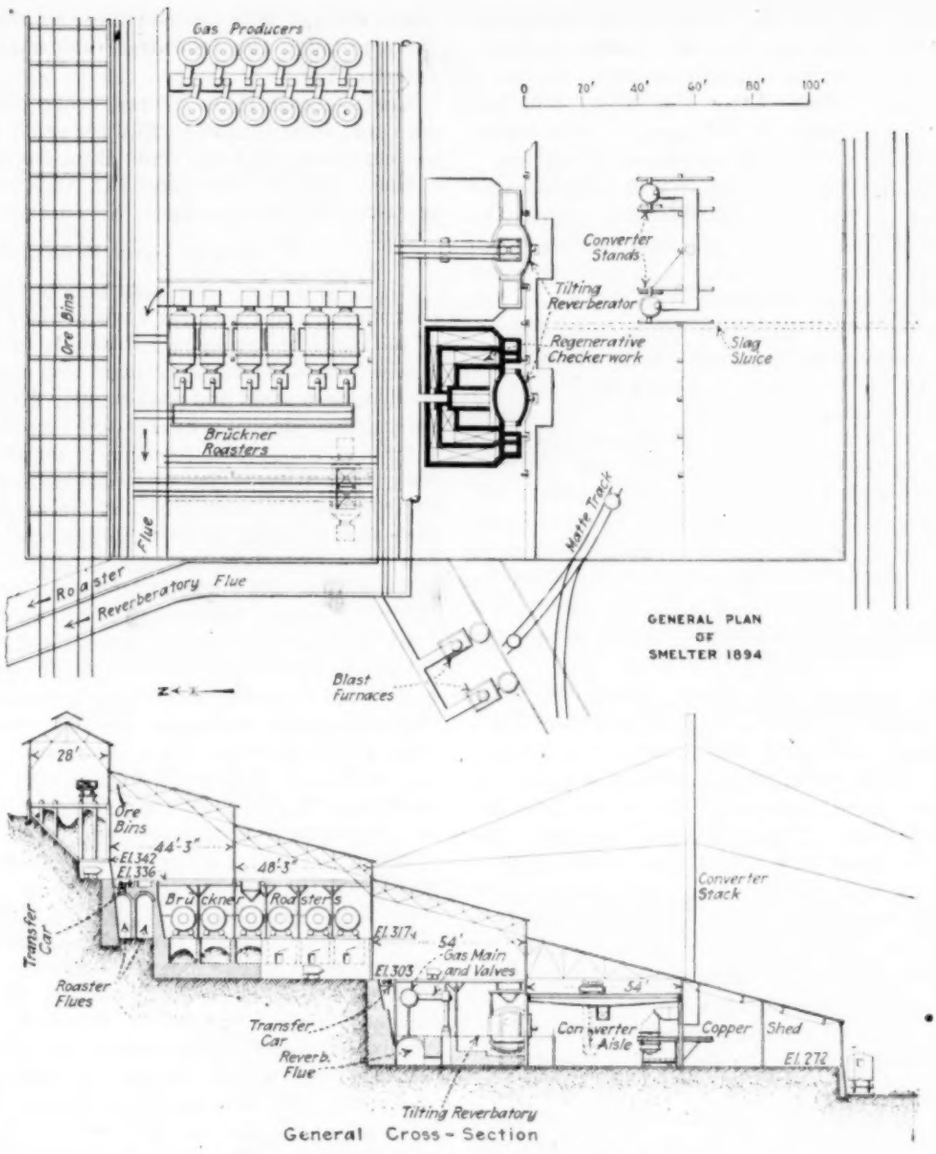


FIG. 2. GENERAL DRAWING OF SMELTER, 1894

bottom and tuyere section of the converter would need relining at intervals, but operation quickly demonstrated that corrosion went higher, and the lining had to be rebuilt after about five blows. For this reason one stall was out of commission constantly, and two more stands were immediately constructed in order to treat all the matte. An interesting forecast of the well-known propensity of Great Falls engineers toward large converters is that as early as the middle of 1892 Manager Klepetko reported that serious consideration was being given to the question whether larger converting shells would not be advisable. The steady growth of these embryonic ideas has been interestingly set forth recently, however, by Messrs. Wheeler and Krejci in the Montana volume of the Transactions of the American Institute of Mining Engineers, and therefore need not be repeated here.

Troubles in Gasifying Low-Grade Coal

Most of the grief in the smelter could be traced back to the gas-producers, however. With from six to eight reverberatories in operation, 350 tons of calcine could be easily handled, even if one of the furnaces was used as a matte well. This was the equivalent of 1000 tons of concentrating ore such as was being delivered to Great Falls (7 to 9 per cent copper!) or even less of the even richer "second class" ore then being treated at Butte. The Great Falls concentrator's product analyzed about as follows:

Copper, per cent	14 to 18
Sulphur, per cent	39
Silica, per cent	13
Iron, per cent	28

All of this had to be smelted in the reverberatories, so no coarse concentrates were made. Indeed, in order to supply the deficiency in calcine considerable first class ore (40 to 50 per cent copper) was fine-crushed in the smelter and sent to the Brückners! The reverberatories seemed to work fairly well when supplied with good gas and hot calcine (sulphur 8 per cent) producing a matte with 50 to 60 per cent copper and containing 19 to 20 oz. of silver per ton of blister. A satisfactory slag ran about 30 per cent silica, 60 per cent iron oxide, 8 per cent alumina, 0.6 per cent sulphur, and 0.7 per cent copper. Converter slag was handled as follows: After a reverberatory had been tilted and skimmed, a ladle of

hot converter slag was run into the matte-furnace, when the intimate contact between slag and "copper bottom" reduced the copper content to approximately that of a normal reverberatory slag. After a sufficient time had elapsed with the furnace under gas, it was again skimmed and was ready for another charge of calcine.

By the spring of 1893, however, it was demonstrated that the method of heating was defective. With the dusty, low-volatile, high-ash fuel available, it seemed impossible to make rich gas continually. In order to smelt at all, then, very hot calcines were essential, which the Brückners would only produce from a fine, dusty charge. To complicate matters, the producers were placed on a bench some 45 ft. vertically above the regenerator ports (see general cross-section in Fig. 2), and it was therefore necessary to run them under high pressure in order to force the hot gas down into the checkerwork. This in turn necessitated high blast-pressure on the producers, with an attending high content of CO_2. Troubles were multiplied in winter, when the occasional stretches of severe weather separating the ever-blowing chinooks would freeze up everything—even a water pipe with a fire under it would not remain open through a week of 30 below!

It was many months, even years, before all these troubles were straightened out. Taylor producers were immediately bought and tried with somewhat more success. Finally a tight, warm, stone building was erected at a low elevation across the end of the converter aisle, and producers, largely of local design, installed. As shown in Fig. 4, these were cylindrical shells, with a rotating grating ring. Ashes were periodically raked out from the pit into sluices. Steam jets injected combustion air into the charge, and gas was drawn off below a revolving top, from which projected four water-cooled stirring arms. The coal itself had to be crushed to hazelnut size and all fines carefully screened out—a mechanical feeder periodically dropped a quantity of this clean nut into the shaft. Slack from the coal crushing and screening plant was trammed to a boiler house and used to make steam for the blast; any excess was sluiced to the river. The gas itself was very sooty and dusty even when made of this clean nut, and the gas mains were consequently enlarged to ample capacity, and provided with the necessary drains and manholes so that the accumulation of fluffy carbonaceous material could be hosed out at relatively short intervals. As an illustration of the material these producers gasified and their product, the following 1910 analyses may be interesting:

Coal:—Total H_2O, 7.7 per cent; combined H_2O, 1.3 per cent; volatile matter, 27.0 per cent; fixed carbon, 48.8 per cent; ash, 22.8 per cent; B.t.u. 10,173.

Gas:—CO_2, 9.2 per cent, CO, 13.9 per cent; CH_4, 2.1 per cent; H_2, 15.4 per cent; N_2, 59.4 per cent.

Reflex Upon Finances

All these troubles could not help but be reflected in the cost sheets, and the Great Falls project was an easy butt of all kinds of criticism. Previous to its inception the newly formed B. & M. company was able to show a very good balance sheet and paid regular dividends—its Butte plants were smelting nearly 400 tons of ore per day, at a cost of about 9¼c. per lb. of copper in matte f.o.b. New York City. These profitable operations still continued, and the new plant at Great Falls was not at first able to equal their performance. About $900,000 had been expended for new construction, the smelter had been put into operation months later than promised, and was possibly absorbing all the money Butte operations were able to clear, since no dividends were being paid, even at an average price of 10⅞c. for copper. "B. & M." was regarded as a highly speculative issue on the Boston mining exchange, and was steadily declining from about 35, when the new smelter started, to 16 in the middle of 1893. Of course, the general panicky conditions of this year were reflected in this price, but the quotation was only 26 when dividends were finally resumed in 1894. As a matter of fact, the B. & M. weathered the free-silver storm more fortunately than other Butte companies—it was the only concern which operated continuously throughout, producing about 3,000,000 lb. of copper monthly. (In the fall of 1893 not more than 500 men were at work in the Butte mines as compared to the payroll of 9000 six months before.) According to the annual report the company apparently was insolvent with a balance of $450,000 in liabilities on July 1, 1893, but this was changed in three months to an asset balance of $205,000. Compare quotations of 16 to 26 with the price of around 475 just before the stock was withdrawn from listing after the company's absorption by Amalgamated!

Changes and Additions in 1893

In the face of such conditions it required no little courage to recommend further expansion at the new

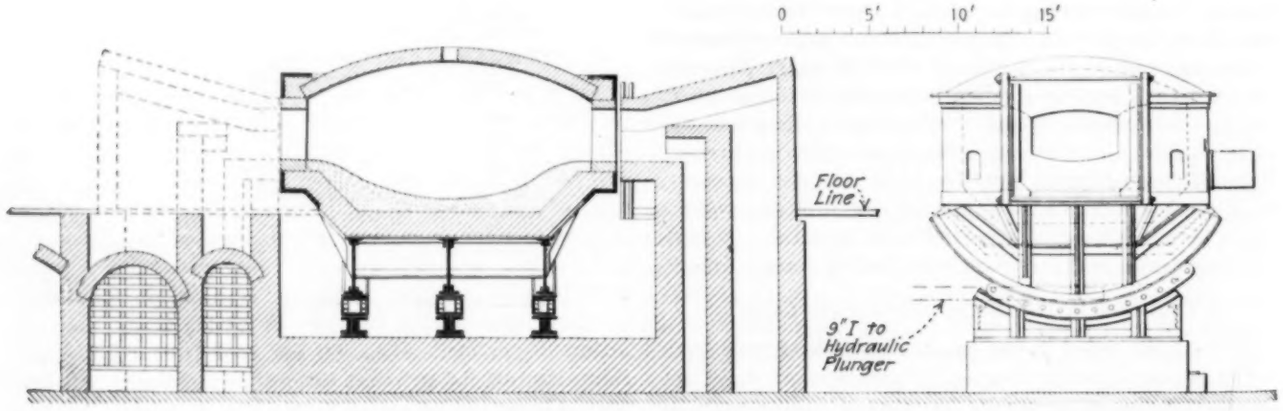


FIG. 3. OPEN-HEARTH FURNACE FOR COPPER MATTE, 1894

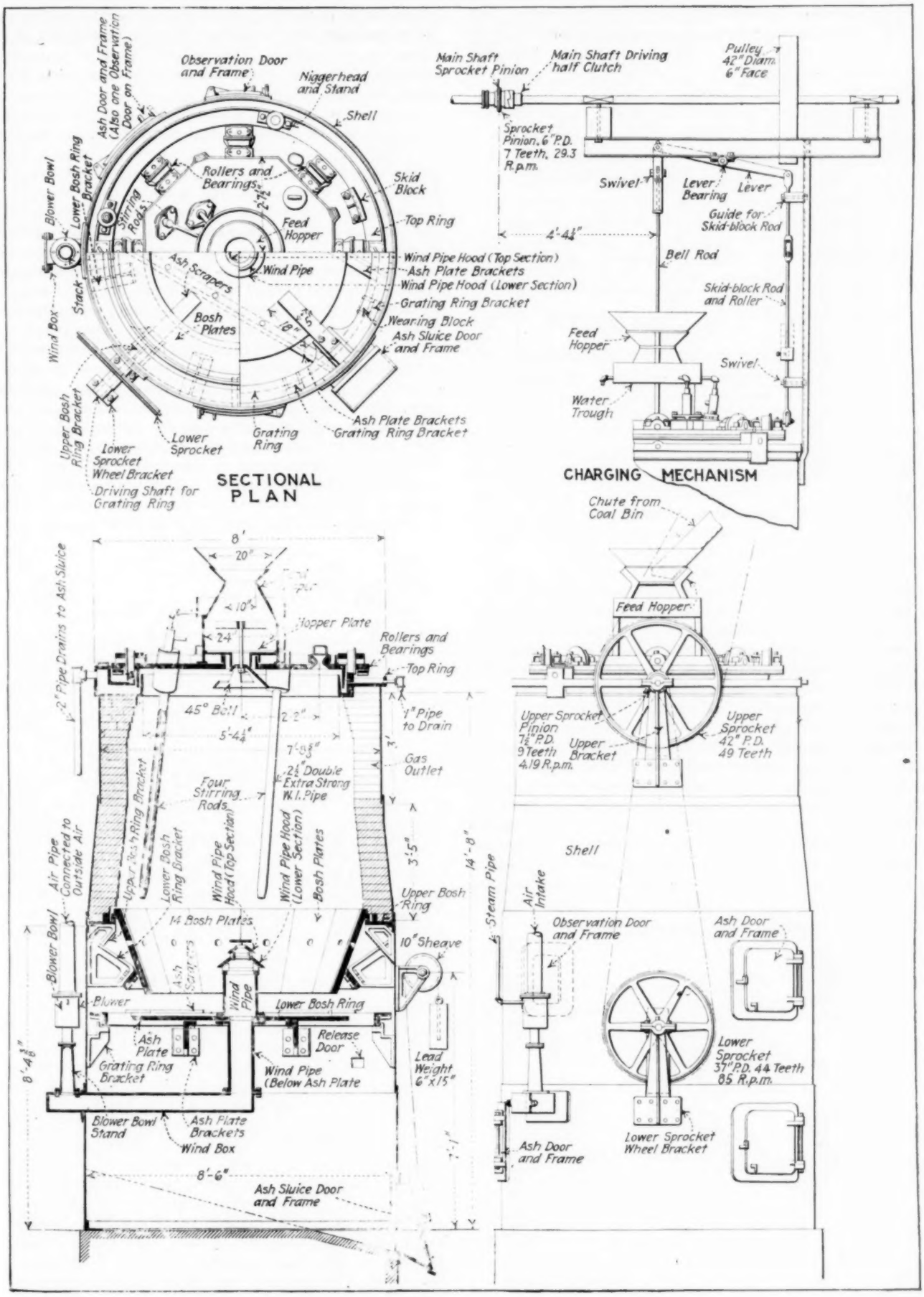


FIG. 4. AUTOMATIC GAS PRODUCER—GENERAL DRAWING

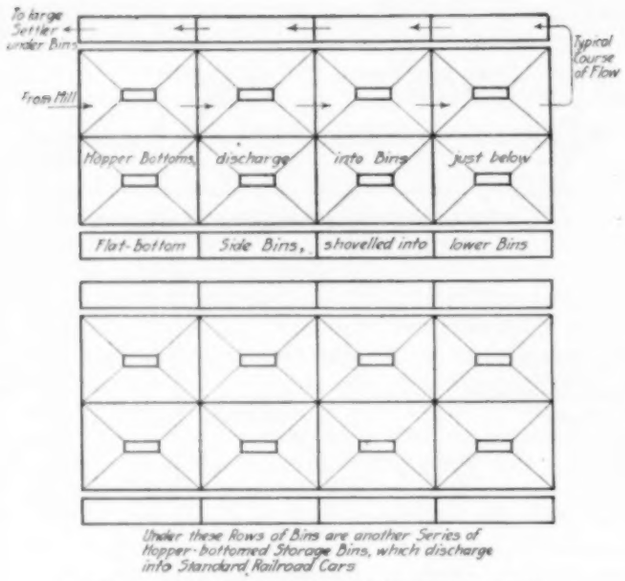

To large Settler under Bins
Typical Course of Flow
From Mill
Hopper Bottoms, discharge into Bins just below
Flat-Bottom Side Bins, shovelled into lower Bins
Under these Rows of Bins are another Series of Hopper-bottomed Storage Bins, which discharge into Standard Railroad Cars

FIG. 5. ONE SECTION OF CONCENTRATE BINS

plant. Yet it appeared logical and was done. The undoubted economies of the new plant were abundant water power, cheap coal, and greatly reduced freight on copper over the 55 per cent matte previously shipped. The installation of a converter department had effected great economies, since large sales of Montana matte in Liverpool were made at 10c. per lb. of copper when Lake was commanding 15, the seller losing all silver under 30 oz. per ton. In order to save the silver lost in Eastern refining, the construction of a 1,000,000-lb. electrolytic refinery costing about $250,000 was rushed to completion after the smelter commenced operation. This consisted primarily of a low brick building 110 by 174 ft. in dimensions, containing 228 tanks. Low voltage electric current was generated by three 180-kw. multipolar Thompson-Houston machines driven by a pair of 39-in. wheels, and transmitted over 22½-in. copper wires. Later, when the capacity of the refinery was increased to 3,000,000 lb., power was generated by a pair of 66-in. wheels direct-connected to two 4500-kw. 220-volt direct current generators, and the power delivered some 2000 ft. over a pair of heavy copper barlines, supported on a low wooden trestle. A furnace-refinery building

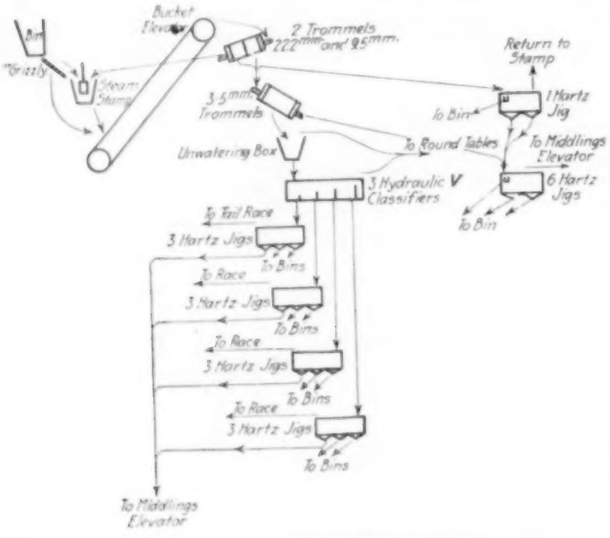


FIG. 6. STEAM STAMP SECTION, 1894

of iron with two small coal-fired reverberatories for refining cathodes, and a number of small auxiliaries completed the installation. This refinery operated quite successfully from the start, handling 50 per cent more metal than the original plans.

Extra converters and a Tod blowing engine were installed to handle Butte & Boston matte in the middle of 1893. The concentrator flow sheet was also altered somewhat in the fall of 1893, when the hutch concentrates from the finishing jigs and also from the tables and vanners were settled in small tanks in the lowest part of the mill, as sketched in Fig. 5. The overflow was elevated to a bin in the upper part of the mill holding coarser concentrates in the hope that the slimes might be filtered out. The cups from the third row or 2.5-mm. jigs were regarded as a middling, while the second hutch product was also sent to the elevator and recrushed; tailings from these jigs went directly to the river. High silica products were also recovered from corresponding portions of the last row of jigs, treating recrushed middlings, but this material was sent to concentrate bins because there was not fall enough to get them back into the elevator. A steam stamp section, with the flow sheet about as shown in Fig. 6, was also installed in the concentrator. This was seldom used, however, on account of the large amount of fine slime it produced, being regarded as a spare to operate only

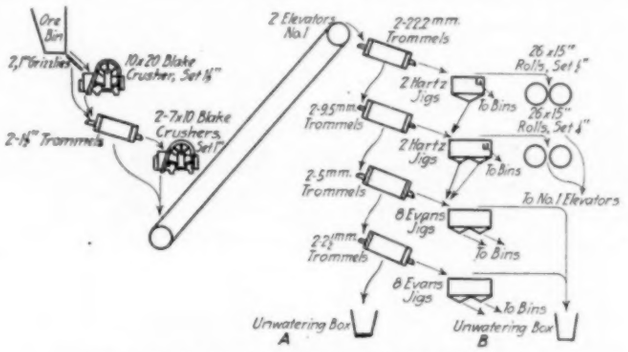


FIG. 7. COARSE CONCENTRATE DIVISION, 1897

during bad breakdowns in the roll sections. I believe it was in existance until 1897, however, when the third crusher and roll section used this part of the building, a new middlings section being installed in an annex. The steam stamp still exists and does yeoman duty, however, being converted into an air-operated hammer for the blacksmith shop.

A Blast-Furnace Found Essential

Smelter operations during 1893 quickly impressed Mr. Klepetko with the fact that blast-furnaces were urgently needed. Much ore was being delivered to the plant containing 40 to 50 per cent copper which could not be concentrated, and if sent to reverberatories, had to be finely crushed before it would satisfactorily roast and deliver a hot calcine. A mountain of converter slag had also accumulated with little promise of recovering the 2 to 5 per cent copper contained. In addition to all this, fine crushing second-class ore caused much sliming and high mill tailings. Coarse concentrates to be smelted in blast-furnaces would remedy these crushing troubles, and even if they were not of very high grade it would be best for the entire system to remove them early in the game. Consequently two small blast-furnaces were erected in a light building placed near where the present

blast-furnaces are, but in order to economize on excavation, set at an angle with the main smelter building as shown in Fig. 2. At first, matte from a small forehearth was cast from time to time in molds, broken and remelted in reverbertory furnaces. Soon larger settlers were built, and a matte ladle car hauled the liquid to a point under the converter craneway. These blast-furnaces were running early in 1894 and gave great satisfaction, bringing operations to a point where abandonment of concentrating and smelting in the Butte properties was justified. Mr. A. T. Elliott was engaged by Mr. Klepetko to take charge of the blast-furnace operations, coming with a crew of experienced furnace men from Argentine, Kansas—then a very important lead smelting center! Mr. Elliott was thereafter closely and honorably connected with the metallurgical operations for over twenty years, acting as general smelter foreman for a large part of that time.

Mr. W. J. Evans also arrived from Michigan at about the same time, to become mechanical superintendent. He, however, gave almost his whole attention to the mill, which now of course had to be remodelled to produce the necessary coarse concentrates for the blast-furnaces.

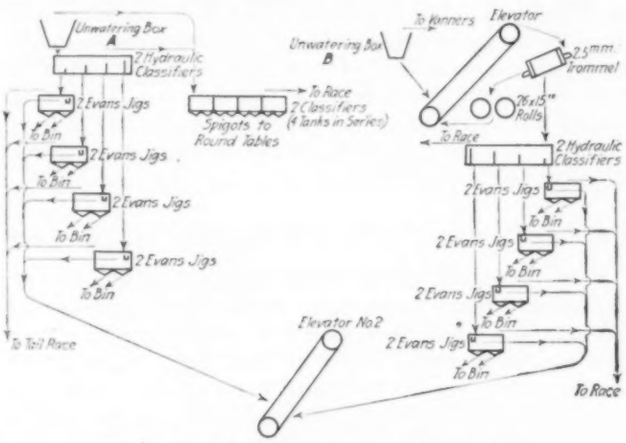


FIG. 8. FINE CONCENTRATE DIVISION, 1897

More attention was also given to the recovery of values from low grade middlings: the final result of a gradual change was the flow sheets given in Figs. 7 to 9 operating in the original wooden building. Briefly, the first coarse jigs were replaced by 2-compartment Hartz jigs and the crushing size increased from ½ to ¾ in. (later to 1¼ in. when two one-compartment bulljigs were installed for this coarsest material). Screen sizing was installed in place of hydraulic classification wherever possible in order to avoid the addition of such large quantities of water. Middlings were roll-crushed as before, but a "middlings-section" was later added owing to the fact that the tails from the middlings jigs were too rich to throw away. No tailings were allowed to go to waste coarser than 3 mm., but even then they would carry a considerable amount of metal—especially the jig tailings would run up to 1.5 per cent copper, while vanner tailings would run as high as 1 per cent. Jig tailings were therefore recrushed in Huntingtons, classified, and concentrated on fine jigs, round tables and Frue vanners (Fig. 9). During this time Mr. Evans also developed the so-called Evans jig, which was almost universally used on Butte ores for over ten years. This improvement was made by changing the rocker arm motion of the Collom jig to a rectilinear motion from an eccentric operating between two horizontal bars. This motion was put on the old Collom hutches, the

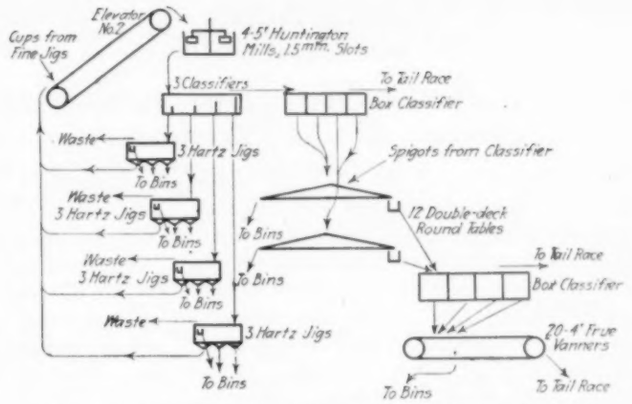


FIG. 9. MIDDLINGS DIVISION FOR THREE CONCENTRATOR SECTIONS, GREAT FALLS MILL, 1897

plunger area being modified correspondingly.

From my note book Table I on concentrator operation during 1894 may be interesting and worth recording. The ordinary operating labor (11 and 13-hr. shifts) per day was one foreman, two assistant foremen, two oilers, two rollmen, 16 jigmen, 2 tablemen, 2 vannermen, 2 cleaners, 2 carpenters, 2 firemen, 1 machinist, 2 machinist helpers, 1 pipe fitter, 2 tankmen, 1 slimer, 1 roustabout, 8 to 10 extras on a 10-hr. day shift for helpers, special changes, new construction and repairs.

Conclusion

By the beginning of 1894, therefore, the new plant was operating very nicely. The company's report showed that the Great Falls work had cost a total of about $2,100,000 and that the cost of copper had been reduced to about 8c. per lb. (a reduction of about 1c. over the previous year) with an average selling price of 9.2c. During that year some 4.7 per cent copper ore had been mined and sent to Great Falls—the lowest grade ore in Butte copper history! The average content was near 7.5 per cent—about 500 tons daily. Dividends were resumed a few months later, and the company entered on its phenomenal career as a money maker. During 1894 two more blast-furnaces were added, one of which was resmelting Butte & Boston matte. These first furnaces were replaced three years later by the present blast-furnace installation—which, by the way, has probably now smelted its last charge.

TABLE I. CONCENTRATOR DATA, 1894.

Capacity of concentrator, 2 sections at 250 tons per section.
Water used, 240,000 gal. per hr. for 500 tons.

Power:			
Rope transmission to drive machinery			500 hp.
Pumps			175 hp.
Electric lights			15 hp.
Total			690 hp.
Speed of machinery:			
Rolls	50 r.p.m.	Collam jigs;	
Crushers	300 r.p.m.	1st, 2nd, and 3rd row	125 r.p.m.
36 in. trommels	20 r.p.m.	4th row	130 r.p.m.
Hartz jigs	140 r.p.m.	Slime tables, 1 revolution in	1.5 min.
Slide-arm jigs	140 r.p.m.	Elevators, 300 to 400 ft.	per min.
Cost in 1894:			
Tons concentrated			170,000
Labor, (average crew 52½ men per day) or $3.10 per shift			$59,349
Supplies, (castings, shells, screens, belts, lumber, and misc.)			34,336
Concentrate, handling and transfer			6,863
Boiler house expense (heat and reserve power)			5,126
Shops (machining and smithing)			1,911
Power house and transmission (maintenance of wheels, pumps, and generators) or $11 per hp. yr.			7,558
Miscellaneous operating account			4,297
Unloading ore, overhead, and other distributable expense			11,920
Total cost for 1894			$131,360
Less construction accounts			9,464
Net concentrating expense or about 72c. per ton.			$121,896

Lowest monthly cost, 53c. in June.
Highest monthly cost, 94c. in January.

Legal Notes

By Wellington Gustin

Inspection of Potash Crystals Before Payment and Ex-Dock New York Construed

IN AN action to recover for damages claimed to have been sustained by reason of defendant's breach of a contract to deliver certain crystal chlorate of potash, the defendant set up a counterclaim for damage for the breach of a contract to deliver certain soda ash. Both the complaint and counterclaim were dismissed and both plaintiff and defendant appealed. (B. Brown & Bros. vs. Raritan Chemical Works, 177 N. Y. S., 309.)

The complaint claims an agreement was made between the parties by which the defendant was to sell and deliver to the plaintiff 300 kegs of crystal chlorate of potash at 60c. per lb., immediate delivery, net cash. This agreement defendant failed to keep, according to the complaint. This agreement was entered into on Nov. 29. The defendant replied by introducing the sales memorandum of brokers who handled the transaction. This memorandum sets out the terms as "net cash against the delivery order. Shipment spot." Replying further, the defendant on Dec. 1 presented plaintiff delivery order for the potash crystals and demanded payment therefor. Acceptance by plaintiff was refused without an inspection of the potash crystals, then in a warehouse at Jersey City. The defendant, at plaintiff's request, issued a permit allowing the inspection. This permit reached plaintiff's office at 3:30 p.m. In an accompanying letter plaintiff was told that the goods would be held until 5 p.m., at which time if payment was not received the contract would be regarded as broken by plaintiff's act.

Question Before the Court

So it appears from the facts that the potash crystals were neither inspected by the plaintiff nor delivered by defendant, and the question therefore presented was whether plaintiff had the right, under its contract, to an inspection of the goods before being required to pay for the same. If it had such a right, then the question of whether the opportunity offered by defendant was a reasonable one was a question of fact for the jury, said the court. But the terms of the sale were net cash against delivery order, and those terms conclusively negative any idea that an inspection was to be allowed them. On the contrary, the court said, by agreeing to pay cash on production of the delivery order, plaintiff effectually waived any right to examine the goods. The act of defendant in offering plaintiff a privilege of inspection was a purely voluntary one, without consideration, and no new contract was created thereby, nor was any so claimed. Hence the court affirmed a dismissal of plaintiff's claim against defendant for failure to deliver the potash crystals.

Taking up defendant's appeal on its counterclaim: This claim arises out of a written contract between the parties for the sale of 24 carloads of soda ash at 2½c. per lb. ex-dock New York, net cash against documents, to be bought by plaintiff for defendant. The provision as to deliveries was as follows:

"Deliveries: Shipping instructions to be given by the buyer not later than 20th of the month next preceding the month of shipment. Two cars monthly over year 1917. Shipments from works from January to December inclusive."

None of the soda ash was ever delivered under the contract, as no shipping instructions were ever given by the buyer (the defendant) as required by the contract. The general provision was that shipping instructions were to be given by the buyer not later than the 20th of the month next preceding the month of shipment. The special provision was for two cars to be shipped monthly from the works, from January to December; and these shipments were to be made to whatever points the buyer fixed. The court held that under these conditions the seller was not bound to tender the soda ash to defendant at any particular point, but that the seller had the right to await the shipping instructions, and if these were not received, then to treat the failure to give them by defendant as a breach of the contract.

Said the court: This was not a case where the goods were to be delivered "f.o.b." at the City of New York, or at any particular place. They were to be shipped from plaintiff's works to such place as named by defendant. The clause "ex-dock New York" merely fixed the price as being at that point, in order to determine the responsibility for freight charges. Holding that defendant thus breached the contract, for which it was itself asking damages for subsequent breach of plaintiff, the court upheld the lower court's dismissal of defendant's counterclaim.

Damage During Transit Follows Title to Consignee

That the buyer cannot reject a shipment of goods on its arrival because of damage during transit, the goods having been sold f.o.b. point of shipment, has been held by the Supreme Court of New York in an action by the seller for the purchase price of the goods. It was held that title passed to purchaser by the bill of lading and deterioration in transit was a loss following the title which became vested in the consignee. (Derma-Viva Co., Inc., vs. Kells Co., 176 N. Y. S., 776.)

From the facts it appears that several months before the shipment of goods sued for the plaintiff had written defendant that its terms of shipment were to be "f.o.b. Chicago," and that claims for damages must be made to carrier. This particular shipment was so made on Dec. 19, in boxes marked "Keep From Freezing, Ship in Refrigerator Car." The bill of lading, with invoice, was received by defendant and retained about two weeks without objection. The goods arrived Jan. 5, but were frozen, and these shipping documents were returned by mail to the plaintiff. There had been delay in filling the order. It had been originally mailed to plaintiff's New York agent on Nov. 21, but the court found such delay was not a proximate cause of the damage to the shipment. Title passed by the bill of lading, the goods being sold f.o.b. Chicago, said the court. Defendant's secretary and manager held the shipping documents to await the arrival of the goods, and admits he would have accepted them, had the articles not been frozen. Such loss resulting in transit follows the title to the consignee, so that such a consignee cannot rescind the shipment, where the documents had thus been retained without objection. Hence a judgment for the defendant in the lower court was reversed with directions to enter judgment for the plaintiff.

Production of Copper From Secondary Material

Methods of Sampling Miscellaneous Products Entering the Refinery, Their Treatment in Regular or Special Furnaces, With a Discussion of the Commercial Possibility of Recovering Some of the Impurities as Metallic By-Products

BY LAWRENCE ADDICKS*

IN ADDITION to the circulating products incident to normal copper refining, the plant is often called upon to treat a wide range of metallurgical by-products from outside sources as well as miscellaneous copper-bearing scrap material. Now that matte smelting plants exist on the Atlantic seaboard, there is little reason to consider anything in the nature of ore or matte, but the following list of materials is fairly representative of what offers:

A. Junk.
  a. Lamps, clocks, etc.
  b. Borings and chips.
  c. Wire.
  d. Sweepings.
  e. Coins and alloys.
B. Mill Products.
  a. Wire.
  b. Scale.
  c. Cement.
  d. Stampings.
C. Metallurgical Products.
  a. Cement.
  b. Amalgamation plates.
  c. Secondary pig.
  d. Nickeliferous pig, black copper, etc.
  e. Furnace bottoms.
D. Refinery By-Products.
  a. Silver refinery slags.
  b. Liberator tank cathode products.
  c. Flue products.

There is a suprisingly large tonnage of such miscellaneous material available, and of course a good deal of it is absorbed by relatively small sweep smelters, who generally feed it indiscriminately into a small blast-furnace, making a foul pig which is sometimes given an additional reverberatory treatment and sent back to the market as casting copper and sometimes is sold to an electrolytic refinery. Such work is a very disturbing element in a copper refinery unless the tonnage accepted is great enough to warrant the establishment of regular facilities for handling it. The general questions involved are, first, sampling; second, disposition; third, proper furnace construction; fourth, possible saving of impurities as by-products.

SAMPLING

The sampling of junk is an art in itself. The ordinary junkman, who travels around in a wagon buying what offers, learns in time to make very close estimates of the metal values of such material, but the refinery cannot afford to let its sampling department adopt such methods on general principles.

The first rule in sampling junk is to classify the material. The insulated wire is put in one lot, the bare wire in another, the alarm clocks and automobile lamps in a third, the sweepings in a fourth, the borings in a fifth, and so on. Clocks and lamps have been considered as a class because they are one of the staples of the junk business. Occasionally large lots of Oriental bronze coins come into the market. A noteworthy instance of this was when Japan took over the control of Korea and exported about 6,000,000 lb. of Korean "cash."

The second step in the sampling is to endeavor to get a representative part of each classified pile. Coins or sweepings can be quartered down like so much crushed ore. Wire can be clipped here and there. Borings can be reasonably sampled by selection. The remainder can be handled only by intelligently taking grab samples, and this requires experience and skill.

The third rule is always to take duplicate samples and to hold the lot intact until assays are out, giving an opportunity for resampling if the assays show sufficient lack of agreement to indicate poor sampling.

The next step varies according to the nature of the material. With dirty metallic material, such as wire or borings or sweepings, a burning loss should be obtained by soaking with gasoline where necessary and igniting, noting the weight before and after. With miscellaneous manufactured material, where different metals are used, as in a clock, or containing solder, as in a teapot, the only way is to make a crucible melt of a rather large sample, accounting for the bar, slag and crucible absorption. Often a material has to be sorted into metallics and dust, as in the case of some sweepings. In general, therefore, it will be seen that sampling junk is a tedious and expensive business. Most junk carries some gold and silver values arising from jewelers' sweeps, etc.

Mill products, such as scrap wire, punchings, etc., shipped directly from the wire mill or other factory to the refinery, are much easier to sample. Here the material is already classified and relatively clean. Care must be taken to see that no bimetallic wire has inadvertently found its way into straight copper wire bundles. It would be thought that bright copper wire from primary sources would need no sampling, but there is always more or less grease attached to it, and the true copper content is nearly always several tenths of 1 per cent below standard. Tinned wire will run 1 per cent or more low and bimetallic wire may run 40 per cent low. The refinery in turn makes a small profit in that the wire bars sent out and accepted by the trade as 100 per cent copper in reality run seven or eight hundredths of 1 per cent below this.

Among the metallurgical products two require special mention, amalgamation plates and furnace bottoms. Amalgamation plates are copper sheets which have been amalgamated on the surface and used to collect gold and silver values from finely crushed native ores. The amalgam has been thoroughly scraped off before the plate is scrapped on account of wear or other defect, but nevertheless sufficient gold is retained to make such material relatively valuable. In this case it is necessary to shear the plates up into equal squares of a few inches on a side; then take systematically say every tenth

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square, following such a system of reduction until the sample is small enough to permit of crucible reduction.

Furnace bottoms are very troublesome to handle. They are generally received in large masses which cannot be drilled or broken. They are usually placed in a furnace for treatment by an overhead crane at a time when the roof is out for rebuilding. They cannot be blasted or cut apart and the only way to reduce the size of a large piece is to build a small flue across the top and channel with a hot oil flame.

The only way to sample them is therefore to chip around the edges. Unfortunately they are often quite rich, as silver and gold tend to concentrate in furnace bottoms. The refiner has to make an allowance in the treatment terms to cover the sampling danger when handling such material.

Disposition

There are several places in the process where secondary material can be introduced. The first is the slag cupola, the function of which is primarily to treat the anode and wire bar furnace slags and which always has capacity to spare. Nearly anything in the scrap line can be introduced here, but it does little more than extract the metals contained and put them into compact shape. Their chemical treatment requires oxidation, which cannot be obtained in the strongly reducing atmosphere of a black copper cupola. Plants treating junk exclusively usually make a blast-furnace melting their first operation, using some briquetting or sintering apparatus to take care of the very fine material before charging.

The usual point of entry is the anode furnace. This insures saving the silver and gold contents and getting the copper in electrolytic form, neither of which is possible to the small junk smelter.

There are certain objections to introducing such material into an ordinary anode charge. In the first place, it is usually in such shape physically that it will take up a disproportionate amount of space in the cold charge. This can be met to a certain extent by charging it at the recharge period when there is plenty of room in the furnace. Then impure material delays the blowing and skimming, and it is important that the furnaces operate on schedule time. Finally, quicker work and better elimination of impurities as well as a better slag concentration for possible by-product recovery are made by treating impure material without dilution. This leads to setting an anode furnace apart for special work at least part of the time. This has another great advantage in that it allows direct costs of the work to be kept.

Then we have the refining or wire bar furnaces. Nothing should be added to a cathode charge regarding which there can be any question as to quality. It is customary to include as admissible, however, scrap wire baled in "cabbages" which originates at standard wire mills. In ingot charges, where conductivity requirements are not quite so strict, liberator cathodes from the first row of tanks in the purifying system may be added with discretion.

Finally, we have the possibility of using a special refining furnace for the production of casting copper. This is attractive in that it enables material which is practically free of silver and gold and high in copper—scrap brass for example—to be worked directly into a marketable product. The disadvantage is that casting copper has no stable market. It always sells at a discount and at times is nearly unsalable.

Until recent years the standard refining reverberatory has been constructed of silica throughout. In some special cases a silica brick bottom has been employed, but the usual construction was silica sand bottom with silica brick sides and roof. Such a furnace is built with a cooling vault, cast-iron bottom plates mounted on brick piers, and a false bottom of fire-clay brick. The vault should be arranged with consideration of a possible run-out of copper through the bottom. It is desirable to lead the molten copper away from the vault before it sets, so that it can be recovered without tearing down the entire furnace, but it is equally essential to see that it does not run into the casting wheel pit or ash pit, where it will probably come into contact with water and cause serious explosions. When a break-out occurs the only thing to do is to charge cold copper into the furnace to set the charge, which is not difficult on account of the high heat conductivity of copper; but if explosions are occurring it is not safe to approach the furnace.

A sand bottom must be carefully impregnated with copper, and an excellent way in which to accomplish this is to mix the sand with about 30 per cent of its weight of copper oxide scale. This is thoroughly turned over and shoveled into the previously dried furnace, where it is calcined at a moderate heat for about 12 hr. The fire is then dropped and the floor carefully leveled and tamped down. The furnace is then fired at maximum temperature—perhaps 2700 deg. F.—for 24 hr. and the furnace after cooling is ready for a small seasoning charge of scrap wire or similar light material. This charge, amounting to perhaps 10 per cent of the rated capacity of the furnace, is melted and ladled out, and after another brief cooling, one twice as large is put in. After this has been ladled the furnace should be ready for service, although it should not be crowded for a few charges, starting at 50 per cent capacity and working up.

This furnace, even when treating high-grade material, will be more or less fluxed by the cuprous oxide of the charge, the silica of the slag being taken chiefly from the bottom of the walls near the metal line. The old treatment for this was "fettling," or plastering corroded spots with fire clay, after each charge was cast.

Prolonged heating in the treatment of foul charges is apt to smelt some of the bottom of the furnace, and when pieces of the bottom begin to "float up" there is always danger of a run-out. Also if elements such as lead are present in appreciable quantity the litharge formed will hungrily attack the silica of the furnace. In fact, a good silica furnace can be easily ruined by a single charge of leady copper. More than 2 per cent lead is always cause for great anxiety.

After a while magnesite and chrome brick were tried as a lining material for the walls of the furnace near the metal line. Approved practice was the use of magnesite for the zone protected and the introduction of one course of chrome brick between the magnesite and silica of which the wall was continued up, the chrome acting as neutral material between the basic and acid bricks.

Magnesite brick spalls badly when exposed to sudden temperature changes. Chrome brick is not subject to this objection, but fails because of softening when exposed to heavy thrust when highly heated.

The next step was to use a chromite verb with great gain in heat control of the furnace, since small dimensional changes from the cutting away of the verb cause great differences in the characteristics of a furnace.

Then the complete basic furnace was developed with magnetic bottom and chrome walls and roof. (Addicks

and Brower, U. S. patents 1,083,719 and 1,148,814.) The sand bottom furnace is constructed with the bottom inside the walls; the basic brick furnace is built with the walls standing on the bottom in order to carry the thrust of the inverted arch directly through to skewbacks reacting against the brickstaves.

With complete basic furnaces it has been found possible to treat material high in lead, and which may require heavy firing for several days without damage to the furnace, so that clean anodes may be made from foul sources of supply.

By-Products

Tables I and II give an idea of the character of some of the low-grade material offering in quantity.

An examination of these analyses shows that aside from copper, the main value, there are often present considerable quantities of gold, silver, nickel, cobalt, lead, zinc and tin. Where gold and silver are present in sufficient quantity to pay the cost of electrolytic treatment, the furnace product should obviously be anodes. Where the silver and gold values are low, casting copper may be considered as a product, but the time required for refining, market deduction for casting copper, values and costs must be carefully balanced in making a decision.

TABLE I. ANALYSES OF CEMENT COPPER

Source	Oz. Gold	Oz. Silver	Per Cent Copper	Per Cent Iron	Per Cent Insoluble
United States	Trace	3.6	80.93	1.40	8.80
United States	0.01	5.3	71.53	1.30	17.06
United States	0.20	11.0	60.58	10.00	1.68
Australia	0.45	0.32	78.28	3.97	3.50
England	0.05	19.8	76.62	5.20	1.63
Belgium	Trace	0.40	69.51	8.50	2.24
Unknown	Trace	0.20	32.18	26.02	5.99

When any of the other impurities are present in quantity, we may consider the possibility of their recovery in slags, in flue products or through the electrolyte purifying plant. In the formation of slags the elements oxidize in the order of their basicity. Their relative affinities for oxygen may be judged by the heats of formation of their common oxides, as follows:[1]

Au_2O_3	−11,500	CoO	+ 64,100
Ag_2O	+ 7,000	FeO	+ 65,700
CuO	+37,700	ZnO	+ 84,800
PbO	+50,800	SnO_2	+141,300
NiO	+61,500		

From these figures we should expect to get first the tin, then the zinc, then the group of cobalt-nickel-iron, and finally the lead, leaving copper-silver-gold in the metal bath. In practice, however, we have to consider the fusibility of these oxides and the readiness with which they form silicates. The situation is quite different from ore smelting in that we are dealing with metallic alloys and always in the presence of a preponderating amount of copper.

The possibility of recovering tin from secondary copper such as given in Table II is indicated in Table III.

TABLE III. TIN RECOVERY

Input

Material	Weight	Per Cent Sn	Contents
Fine bullion	53,567	3.19	1709
Fine bullion	50,874	3.30	1679
Fine bullion	61,125	2.07	1265
Fine bullion	51,918	2.23	1158
Fine bullion	54,027	2.10	1135
Fine bullion	54,440	3.02	1644
Furnace returns	6,000	0.27	16
Anode scrap	30,000	0.15	450
Total	361,951	....	9056

Output

Material	Weight	Per Cent Sn	Contents	Per Cent Sn Input
Anodes	178,801	0.61	1701	18.8
First slag	7,686	0.38	29	0.3
Second slag	17,796	0.78	139	1.5
Third slag	39,657	14.43	5722	63.2
Metallics	4,019	0.61	25	0.3
Unaccounted for	13,992	.....	1440	15.9
Total	361,951	.....	9056	100.0

There has been collected in the third slag 63 per cent of the tin. If we take the copper in this slag at 25 per cent, we shall have upon reduction to metal a foul alloy running 30 to 35 per cent in tin, a reasonable first step toward the recovery of this metal.

Zinc is not a sufficiently valuable metal to warrant the cost of its extraction from impure or low-grade products. Inasmuch as a copper furnace is operated at a temperature above the boiling point of zinc, it would be possible to make a certain recovery as fume, but as this would be contaminated with other volatile impurities such as arsenic and antimony present in foul bullion, such an operation would have no commercial standing.

While iron, cobalt and nickel stand close together in the heat of oxidation scale they show a marked difference in slagability. In fact the ease of removal in a reverberatory furnace might be arbitrarily indicated as 1.00 for iron, 0.10 for cobalt, and 0.01 for nickel.

TABLE IV. RELATIVE SLAGABILITY OF IRON, COBALT AND NICKEL

	Original Bullion	After First Refining	After Second Refining
Copper, per cent	94.55	99.42	99.66
Iron, per cent	3.04	0.011	0.008
Cobalt, per cent	0.894	0.023	0.024
Nickel, per cent	0.408	0.110	0.109
Iron	1.000	0.004	0.003
Cobalt	1.000	0.026	0.027
Nickel	1.000	0.270	0.266

This is illustrated in a general way by some published[2] data of experiments conducted in a 2-ton furnace at the Wysk smelter in Russia, some of the results of which are shown in Table IV.

Iron is of course far too cheap a metal to be considered as a by-product except in very large-scale ore smelting operations. It can be easily removed from copper bullion by slagging, but not without the corresponding renewal of a small amount of the copper as cuprous oxide, which forms the scorifying agent.

Cobalt can be removed with reasonable facility in

[1] Values from Richards' "Metallurgical Calculations."

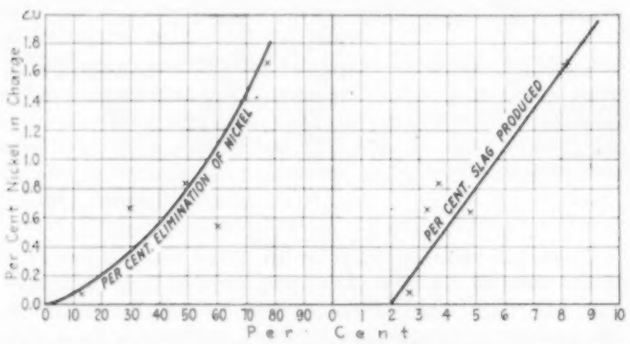
[2] Hofman's Metallurgy of Copper, p. 391.

TABLE II. ANALYSES OF FOUL COPPER BULLION

Material	Source	Oz. Au	Oz. Ag	Per Cent Cu	Per Cent Ni	Per Cent Co	Per Cent As	Per Cent Sb	Per Cent Bi	Per Cent S	Per Cent Fe	Per Cent Pb	Per Cent Se	Per Cent Te	Per Cent Zn	Per Cent Sn	Per Cent Insol.
Black Cu	Australia	0.24	2.0	.....	0.89	.....	0.22	0.20	0.06	0.86	0.01	.....	0.01	0.01	.....	.....	.....
Black Cu	Africa	0.003	0.15	90.25	Trace	5.59	0.10	.....	.....	1.32	2.05	None	.....	.....	.....	.....	.....
Secondary Cu	United States	0.12	7.8	84.77	0.24	.....	0.04	0.23	None	0.55	3.19	3.09	Trace	Trace	3.17	2.07	0.56
Blister	United States	0.40	9.0	97.80	1.28	.....	0.002	0.003	Trace	0.04	0.07	0.005	0.08	0.006	0.03	.....	0.14
Black coins	Korea	0.08	6.2	67.48	....	.....	2.15	0.06	0.01	.....	1.87	24.10	Trace	.....	4.27	.....	0.08
Yellow coins	Korea	0.12	5.9	56.73	....	.....	0.47	1.15	0.03	.....	1.35	9.31	.....	.....	30.81	1.02	0.18
Secondary Cu	United States	0.09	6.2	85.01	0.35	.....	0.03	.....	.....	0.94	0.92	5.49	.....	.....	1.60	4.21	0.11
Secondary Cu	Europe	....	...	75.66	0.40	.....	.....	0.15	.....	.....	0.89	2.37	.....	.....	19.12	1.38	.....

like manner and collected in a slag running perhaps 20 per cent cobalt and 20 per cent copper, but really cobalt-free copper could not be produced without slagging a large amount of the copper in repeated scorifications.

Nickel is much more difficult to deal with, and is generally recovered by separation as a soluble sulphate in electrolytic refining. Considerable data are available on its behavior in the anode furnace. An example of some large-scale experiments is given in diagrammatic form in the illustration, and these curves are analyzed in Table V.



BEHAVIOR OF NICKEL IN THE COPPER REVERBERATORY

TABLE V. BEHAVIOR OF NICKEL IN THE COPPER REVERBERATORY

	Per Cent				
Nickel in charge	0.0	0.5	1.0	1.5	2.0
Elimination	...	37	57	72	81
Nickel in product	0.0	0.32	0.44	0.45	0.40
Slag	2.0	3.8	5.7	7.6	9.4
Nickel in slag	0.0	4.9	10.0	13.8	17.1

It is evident that more prolonged working of the charges richer in nickel would result in a somewhat lower nickel in the product and a larger quantity of slag lower in grade as to nickel, but it is quite out of the question to reduce the nickel tenor of a large charge to the degree shown by the small Wysk furnace. The slag, if treated in a matting furnace for the recovery of copper, will lose a large part of its nickel to the new slag; if treated in a black copper cupola, the nickel will be nearly all reduced with the copper.

Lead is readily separated from molten copper as litharge. As this active base rapidly attacks siliceous material, quite small quantities of lead demand a basic furnace for safe handling. Lead is practically insoluble in pure copper, but in the presence of sulphur or various impurities it is absorbed, and considerable quantities are found in secondary copper and occasionally in blister where leady copper ores have been treated. Certain bearing metals are made of a mixture chiefly of copper and lead, and the black Korean coins listed in Table II showed high percentages of lead. When melting down large quantities of these in a furnace with a basic brick bottom placed over a cooling vault, it was noticed that practically pure lead sweated through the bricks underneath, indicating liquation and a possible means of separating lead from copper. A copper-lead slag which can be profitably smelted for both metals is readily made from such material.

In general, electrolytic refineries recover a large part of any nickel or lead entering their plants in sufficient quantities, and steps would be taken to recover cobalt and tin did the crude copper carry sufficient of these metals, but the disturbance of the process due to interference of these impurities in the main business of copper refining overshadows the possibility of placing impurities on a revenue-producing basis except where large regular quantities have to be dealt with. Where casting copper is made, a portion of these alloy impurities remains and actually improves the copper for certain purposes by increasing its fluidity or altering its color.

The Absorption of Gases in Spray Systems and Towers

By Edwin M. Baker

IN PROBLEMS involving the absorption of a gas by a liquid it is generally desired to absorb or dissolve some one constituent of a gas mixture by the liquid. It will be found convenient to call the gas to be absorbed or dissolved simply the "gas," and the gas mixture containing this gas and other diluting gases the "gas mixture." The absorption of gases in liquids may be divided into three subdivisions of a general class, in which most absorption problems will fall. First, the case where the nature of the gas and liquid is such that a chemical reaction takes place so that the gas will not exert any appreciable vapor pressure after absorption. The absorption of ammonia gas in an excess of sulphuric acid would be an example. Second, the case where the nature of the gas and liquid is such that a chemical reaction takes place, but the compound formed is sufficiently unstable so that the dissolved gas exerts an appreciable vapor pressure. The absorption of ammonia gas in water would be an example. Third, the case where no chemical reaction takes place between the gas and liquid, and where the liquid exerts a vapor pressure directly dependent on the amount of absorbed gas. An example of this is the absorption of the so-called gasoline content of natural gas in heavy mineral oil. Different combinations of gases and liquids may be found which will give a series of conditions gradually shading from the first to the third subdivision. In this general class, then, are included the cases where simple or no chemical reactions take place. It does not include complicated reactions such as take place on the introduction of oxides of nitrogen with excess oxygen in the form of air into absorption towers; where water is used as the absorbing agent to form nitric acid; and where the oxidizing of the lower oxides of nitrogen must be taken into account.

In the general class considered, if the gas mixture and liquid were put in a closed container and left a sufficiently long time, the liquid would absorb the gas until the vapor pressure of the dissolved gas just equalled the partial pressure of the gas in the gas mixture. In case 1 this would be 100 per cent absorption, because the dissolved gas would exert a zero vapor pressure. Hence the partial pressure of the gas in the gas mixture would be zero, and the per cent gas would be 0 per cent. Since the volume of gas divided by the volume of gas mixture equals the partial pressure of the gas divided by the total pressure, then the per cent of gas in the gas mixture equals

$$\frac{\text{partial pressure of the gas}}{\text{absolute pressure of the gas mixture}}$$

In cases 2 and 3 the per cent absorption would be something less than 100 per cent, depending on the nature of the gas and liquid. Suppose we express the nature of the gas and liquid by calling the theoretical percentage absorption, when the liquid and gas are in intimate contact for a sufficient time, at some imaginary standard con-

dition, K. The theoretical absorption under some other condition may be called K'. Then K' may be increased (if it is not already 100 per cent) by increasing the total pressure on the gas mixture, since this increases the partial pressure of the gas, and hence the vapor pressure of the dissolved gas necessary to re-establish equilibrium. And the latter means increased concentration of the dissolved gas. Lowering the temperature of the system will in general increase K', since lowering of the temperature gives a lowering of the vapor pressure of the dissolved gas. Increasing the concentration of the gas in the gas mixture will in general increase the amount of gas absorbed, since the partial pressure of the gas increases in proportion to the per cent composition. Lowering the concentration of the dissolved gas in the liquid will decrease the vapor pressure of the gas, and so increase the amount of gas that will dissolve. The value of K' can be found in the literature for most gases and liquids. Or, at least, information may be found from which a working value of K' may be obtained. Fig. 1 gives various values of K' at 60 deg. F. and 30 in. barometer, for certain concentrations of ammonia in the gas mixture and liquid. A family of such curves would be required to express K' for all conditions.

Rate of Absorption

This, however, does not tell us anything about the rate of absorption under any given conditions. In general, it may be said that the force which causes a gas to be absorbed by a liquid is the difference between the partial pressure of the gas in the gas mixture and the vapor pressure exerted by the gas dissolved in the liquid. With no difference the rate would be zero, and in order to get a rapid absorption of a gas in a liquid it must be understood that theoretically perfect absorption cannot be expected, that is, some difference in partial and vapor pressure must be allowed for.

The rate of absorption also depends on the intimacy of contact between the liquid and gas mixture, and this depends on the design and operation of the particular absorption tower or spray system.

The per cent of the theoretical absorption realized depends on the rate of absorption and the duration of contact of the liquid and gas mixture, the latter also depends on the design and operation of the apparatus.

To sum up, the rate of absorption, R, for a given gas and liquid will be proportional to the product of the difference in partial and vapor pressures, D, times a factor expressing the intimacy of contact, I, or $R = CDI$. The per cent of theoretical absorption, A, will be proportional to the rate of absorption times the time of contact T, or $A = C_1DIT$, and the actual absorption for any gas and liquid will be proportional to K' times A, or actual absorption, $P = C_2K'DIT$.

This formula is not capable of any direct mathematical application, but may be useful in comparing various systems working on different gases and liquids, or for analyzing certain absorption problems. C_2 is the proportionality constant, depending on the units in which the other factors are expressed, etc. K' is the theoretical absorption under the particular temperature, pressure and concentration of entering and exit gas mixture and liquid employed. K' will generally be fixed by plant operating conditions, and may be varied only by changing these. D, the difference in partial and vapor pressures, depends on these plant conditions; and also on the design of apparatus, in that for a given concentration of gas in the exit gas mixture and liquid, and for a given concentration of the entering gas mixture, D will have the effect of being larger with the counter-current flow principle than with parallel-current flow. The effective value of D with counter-current flow will depend on the number of spray systems or towers in series and on the number of effective zones in each unit. I and T will depend on the design and operation of the system as a whole. Increasing the liquid flow or circulation rates will in general increase I, the intimacy of contact, while increasing the volumes of gas mixture handled will decrease both I and T. This formula may be especially useful if a particular system is being used under known conditions and it is desired to know what it, or a duplicate system, will do under different conditions, say using a different gas and liquid. If the same conditions of flow rates of gas and liquid are to be maintained, the formula reduces to (1) per cent of absorption, $P_a = C_2K'_a$, and likewise (2) $P_b = C_2K'_b$, where the subscripts refer to operation under known or desired conditions. Substituting in (1) the known values will give a value for C_2. K'_b may be found from plant or published data. Then the product of C_2 times K'_b will be the per cent absorption under the new conditions. Now suppose it is desired to use some other conditions of flow rates of gas and liquid. If the effect on the per cent absorption of varying these two factors is known for any fixed K', when this is less than 100 per cent, then the K'_b we have obtained may be corrected to correspond. The results so obtained should be sufficiently accurate to act as a real guide in making new installations or to show plainly if some of the towers or systems in use are not giving the proper absorption, due to faulty construction or operation, or to offer a comparison of the capacity and efficiency of widely different systems.

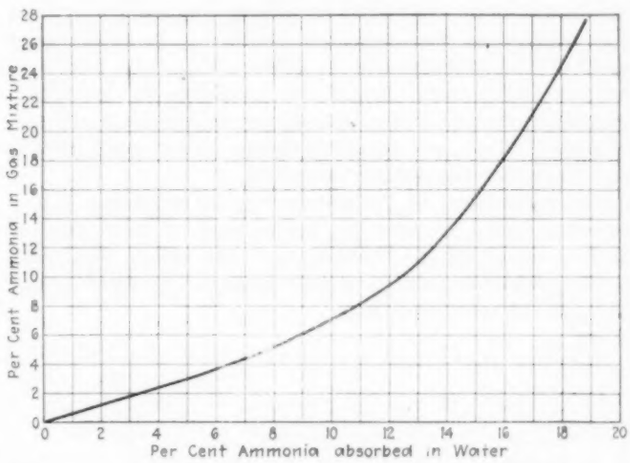


FIG. 1. CONCENTRATION OF AMMONIA IN GAS NECESSARY TO GIVE SOLUTION OF STRENGTH SHOWN. THEORETICALLY PERFECT ABSORPTION

The writer recently made some absorption tests using the spray system for liquid cooling.

Ammonia gas, from cylinders of liquid ammonia, mixed with air, was used as the gas mixture, and city water was used as the absorbing liquid. The per cent of ammonia in the exit liquid and in the entering and exit gas mixture was determined, and the temperatures of the entering and exit water and gas were taken, as well as data to compute the rate of flow of water. The rate of flow water and all temperatures were held

practically constant, while the volume and percentage composition of gas mixture were varied. The composition of the exit gas mixture and water varied as a result of this. Fig. 2 shows the per cent ammonia in the exit gas mixture plotted against the per cent ammonia in the exit water from the spray system, as compared with the amount that would be found for theoretically perfect absorption. At first sight the relative value appears very large, but it should be remembered that the amounts involved are very small. The data shown here are important only in that they show that the per cent ammonia in the exit gas is largely determined by the per cent ammonia in the exit liquor. The curve for theoretical absorption is nothing more than values of K', and since the absorption obtained is proportional to this, it follows that the absorption is taking place according to definite laws, and is not haphazard. If such a relation is found not to exist in any absorption tower or other system, it would be advisable to investigate the tower filling or distribution of absorbing liquid for effective channels where gas is getting by without being acted on. Fig. 3 shows the total percentage of ammonia recovered by absorption plotted against the volume of gas mixture handled. In this spray system, and presumably in others, this was found to be one of the most important variables in operation. Increasing the volume of gas decreases the intimacy and time of contact, and so, other things being equal, naturally decreases the total absorption.

The increasing of the percentage of ammonia in the entering gas increased the percentage of total absorption in terms of the theoretical. The effect was small enough, however, to be nearly hidden by other variations in the test conditions.

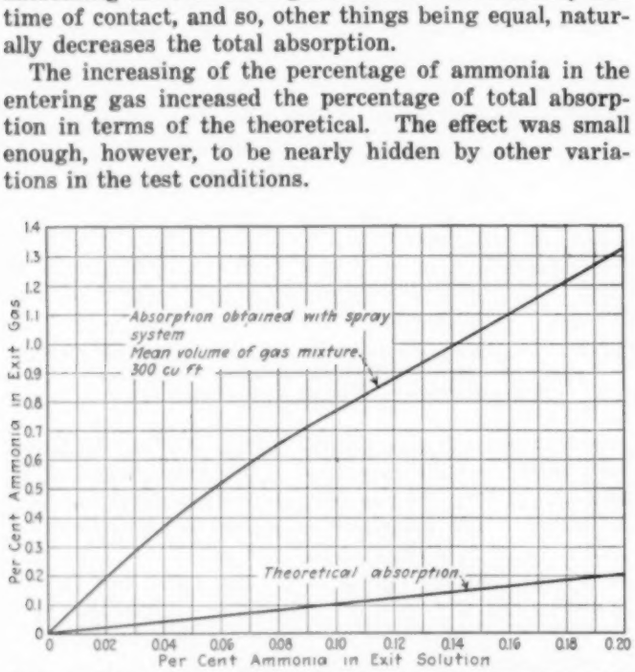

Per Cent Ammonia in Exit Gas
Absorption obtained with spray system
Mean volume of gas mixture, 300 cu ft
Theoretical absorption
Per Cent Ammonia in Exit Solution

FIG. 2. PER CENT OF AMMONIA IN THE EXIT GAS AND SOLUTION FOR ABSORPTION OBTAINED WITH SPRAY, AND THEORETICALLY PERFECT ABSORPTION IN WATER

The flow of water used was such as to give nearly maximum absorption, and the rate of flow was not varied. The curves given are of general importance only in that they may be duplicated for existing installations, and comparisons drawn. In this case the curve in Fig. 3 shows practically the per cent absorption in general operation for this particular system, with flow rates of liquid of about 30 gal. per min. It is practically a series of values for $C_2K'DIT$, and since, according to the composition of the exit water reached, the theoretical absorption should be 99.8 per cent $= K'$, the curve practically gives values of C_2DIT. In other words, if a given volume of any gas is to be absorbed in any liquid, from the curve in Fig. 3 can be obtained the absorption that may be expected for the volume of gas handled; i.e., for 300 cu. ft. per min., this machine would give 75 per cent of the theoretical absorption. This is the value of C_2DIT. Now, if the temperature and concentration of the exit liquid and entering gas are to be such that only 80 per cent of the gas may be theoretically absorbed, the value of K' will be 80 per cent. The actual absorption that will be realized will then be 75 per cent of 80 per cent = 60 per cent of the gas in the gas mixture. Suppose the gas mixture originally contained 50 per cent of the gas to be absorbed, or 150 cu.ft. Of this 60 per cent, or 90 cu.ft., will be absorbed and 60 cu.ft. will pass through. The exit gas mixture then has a volume of 6 + 150 = 210 cu.ft., and contains 60 ÷ 210 = 28.6 per cent gas.

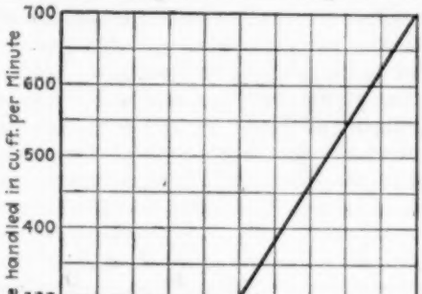


FIG. 3. RELATION BETWEEN VOLUME OF GAS MIXTURE HANDLED AND PERCENTAGE RECOVERY OF AMMONIA

Suppose this exit gas is passed through a second spray system, counter-current flow of liquid and gas mixture being used. Also, to simplify the problem, assume K' to remain unchanged, though in general it would increase in the successive spray systems. For 210 cu.ft. per min. the absorption would be 80.5 per cent of the theoretical, or the total absorption would be 80.5 per cent of 80 per cent = 64.4 per cent. The absorption in the second spray system is then 64.6 per cent of 60 cu.ft. = 38.6 cu.ft. The total absorption in two sprays is then 38.6 + 90 = 128.6 cu.ft. or 128 ÷ 150 = 85.7 per cent of the gas.

The exit gas from the second spray contains 150 cu.ft. of diluting gases and 60 — 38.6 = 21.4 cu.ft. of gas. This gives 150 + 21.4 = 171.4 cu.ft. of gas mixture, containing 21.4 ÷ 171.4 = 12.4 per cent of gas. Suppose this gas to be passed through a third spray system, counter-current principle. The absorption for 171.4 cu.ft. is 83 per cent of the theoretical, or the actual absorption is 83 per cent of 80 per cent = 66.4 per cent. The absorption in the third system is then 66.4 per cent of 21.4 cu.ft. = 14.2 cu.ft., making the total absorption in the three systems 14.2 + 38.6 + 90 = 142.8 cu.ft. and the recovery 142.8 ÷ 150 = 95.2 per cent. The results obtained are low, for a large volume of gas mixture was assumed, and in general the value of K' (which has been considered constant) will increase quite rapidly in the spray systems or towers having the more dilute exit liquid.

The last portion of this paper is subject to considerable elaboration, but this article has aimed rather at giving merely fundamental principles.

Chemical Engineering Laboratories,
University of Michigan.

The Catalyst for the Oxidation of Ammonia*

Description of General Types of Equipment Employed for the Production of Nitric Acid by the Catalytic Oxidation of Ammonia—Platinum as Catalyst—Influence of Space-Time-Temperature Conditions—Conclusions

BY G. A. PERLEY

THE methods involved in the production of nitric acid by the catalytic oxidation of ammonia have been described in a great variety of places. It seems strange to observe the tremendous variations in the general types of apparatus employed in this work when the basic feature must be the same for all equipments where platinum is used as a catalyst.

Some combinations used in commercial practice are:

OSTWALD CATALYST

The use of a preheated mixture of air and ammonia through a heat exchanger in accordance with Ostwald's plans. Platinum sponge or nets were used as the catalyst. A modification of this type has consisted of a nickel tube, 8 ft. long by 2 in. diameter, in the end of which was rolled a piece of platinum foil weighing about 1.6 oz. An enamel-surfaced iron tube surrounds this nickel tube and serves as the inlet for the ammonia-air mixture. The hot gases passing down the inside of the nickel tube transfer a portion of their heat content to the cold ammonia-air mixture flowing up between the nickel tube and the enamel-surfaced iron tube. It is reported that a temperature on the catalyst of from 600 to 800 deg. C. is obtained with a 9 per cent (vol.) NH_3. Such a system requires the use of expensive enamelled iron and nickel, while the production per unit is necessarily small. Again there is no temperature control on such a system, and in actual practice there is a certain amount of pre-decomposition. A production of 164 lb. of nitric acid per day, or the equivalent of the oxidation of 45 lb. of NH_3 per unit, is the reported yield. This gives a capacity of only 28 lb. of NH_3 per oz. of platinum per day. It seems as if this capacity as reported is somewhat low, yet it shows the inefficiency of the use of a solid sheet of platinum.

KAISER CATALYST

A modification by Kaiser of Spandau has been described where heat control was obtained through the separate preheating of the air in a coke furnace to 300 deg. C., and then admixture of this with the ammonia. Dr. Kaiser has claimed a preactivation of the nitrogen of the air by this preheating. His claims of securing 200 per cent oxidation efficiency by this so-called "autoxidation" have been proved most ridiculous. While the catalyst of the Ostwald modification was usually some sort of thin foil, the Kaiser catalyst consisted of four platinum gauzes placed in close contact with one another.

The gauzes were made of 0.0024-in. diameter wire and 80 meshes per linear inch. A catalyst of 0.02 in. total thickness resulted. Kaiser used a gas velocity which he claimed gave a catalyst contact of 0.0006 sec. A square foot of the Kaiser four-layer catalyst probably weighed approximately 6.6 oz., and he has stated a maximum output of about 3750 lb. of HNO_3 per sq.ft. of catalyst per day. The actual plant yields are said to be more nearly 1056 lb. of HNO_3 per sq.ft. per day. On this last basis a capacity of 43 lb. NH_3 per oz. of Pt per day is the result. In view of the recent studies it seems probable that Kaiser could have obtained nearly the 3750 lb. of HNO_3 per sq.ft. of catalyst per day, but the secret was not due to autoxidation.

FRANK & CARO CATALYST

The Frank & Caro type of catalyst consisted of a single platinum gauze made up of 0.0026-in. diam. wire and 80 meshes per linear inch. The gauze was welded to silver terminals and heated by electrical energy to about 650 to 700 deg. C. The type of apparatus used by the followers of this equipment usually consisted of an aluminum frame and a rectangular catalyst 15¾ x 23½ in., with the flow of the air-ammonia mixture going up through the electrically heated gauze. Here precooling of the intake mixture contrasts to the preheating of the Ostwald type. The Bamag Co. has claimed that this platinum gauze, per converter, weighs about 2.89 oz. and that such an equipment oxidizes 176 lb. of NH_3 per day at 90 to 92 per cent efficiency. This is 60 lb. NH_3 per oz. of Pt per day, and is considerably higher capacity than that secured by the Ostwald type (28 lb.). The yields as reported are probably very near correct.

AMERICAN CYANAMID CATALYST

The patents of the American Cyanamid Co., as taken out by Dr. Landis, cover essentially the same equipment as those of the Frank & Caro type, except that a chemically pure platinum gauze is employed, and the size is perhaps a few square inches smaller; also, the flow of the ammonia-air gas mixture is downward rather than upward as in the Frank & Caro type. Even the precooling is protected in the Landis patents. It is interesting to know that in the operation of the Landis converters no precooling device was adopted and a 0.003-in. diam. wire at 80 mesh gauze was used. A capacity of about 50 lb. of NH_3 per oz. of Pt per day could be obtained with 90 to 92 per cent oxidation efficiency.

PARTINGTON CATALYST

A composite of the Frank & Caro with the multi-layer gauze has been used in England and described by Partington.[1] Here an aluminum frame holds two layers of a platinum gauze and the gas flow is up through the first layer, which is electrically heated, and then through a second gauze, which is electrically insulated from the first by small silica rods. In this apparatus it is necessary to use less than 50 per

* A paper read at the Philadelphia meeting, September, 1919, and published by permission of the American Chemical Society.

[1] *J. Soc. Chem. Ind.*, vol. 37, p. 337r; 1918.

cent of the electrical energy consumed by the Frank & Caro type of apparatus. Precooling was avoided by Partington, and although preheating was not employed, it was recommended as desirable, provided the pre-decomposition of the ammonia could be economically prevented. The commercial units employed were small and utilized two layers of a 4 x 6 in. platinum gauze of 0.0025-in. diam. wire and 80 meshes to the inch. Both layers were of the same type of gauze. The gauze weighed 1.6 oz. per sq.ft. An output of 1026 lb. of HNO_3 per 24 hr. is claimed by Partington, and with 95 per cent conversion, and with a gauze temperature of 650 to 700 deg. C. This is equivalent to a capacity of 291 lb. of NH_3 per day per oz. of platinum. This method had been duplicated in the United States and it was never possible under any conditions to obtain these capacities with the published high oxidation efficiencies. The method of determining oxidation efficiencies for a given catalyst unquestionably governs the expression of the gauze rating. Partington recommends in another place a unit with a sectional area of 1 sq.ft. and the two layers of gauze with the electrical heat only upon the gauze which the gas stream meets first. He states that such a catalyst should produce 1 to 1.7 tons of HNO_3 per 24 hr., but the oxidation efficiency may be about 90 per cent.

Bureau of Mines Catalyst

Parsons & Jones have made patent applications for the use of a type of converter developed in some cooperative experimental work by the Bureau of Mines. Here a four-layer platinum gauze is used. The layers are in close contact, and the gauze is made of 0.0026-in. diam. wire and 80 mesh. The platinum gauze alone resembles the Kaiser type. The chief feature in this type of converter lies in the fact that no electrical heat is utilized, nor is there any preheating of either the air or air-ammonia mixtures. By the use of a non-conducting (heat-insulated) converter frame and a cylindrical form of gauze, the temperature of the catalyst is maintained sufficiently high to give oxidation conversions of from 90 to 91 per cent. A capacity of 70 lb. of NH_3 per oz. of platinum per day can be obtained on pure grades of NH_3.

Recent Developments

The nitrate division of the Ordnance Department has found that a decided increase in oxidation efficiency with an added capacity can be obtained, even with impure ammonia mixtures, by the use of a heat exchanger for the air and a subsequent mixing of the heated air with the cold NH_3 just prior to the gauze entrance. A four-layer, close-contact, cylindrical form of gauze of 0.0026-in. diam. wire and 80 meshes per in. was used in the work. The maximum intake temperature which could be secured by the exchanger was utilized. A capacity of 100 lb. of NH_3 per day per oz. of platinum at 95 per cent conversion has been obtained with a 0.0026-in. diam. wire and 80-mesh gauze. This type of converter was developed after operating experience with all other types. It differs from the Kaiser type chiefly by the utilization of the waste heat of the reaction through a properly designed heat exchanger for the intake air of the ammonia-air mixture. The function of the heating of the air is not one of activation or autoxidation, but rather a case of increasing the ammonia-air gas mixture to a temperature above 600 deg. C., without any predecomposition, in order to secure a high reaction velocity when the gas mixture comes in contact with the catalyst for but a short period.

The work of the writer has led him to utilize a heat exchanger for the ingoing air and a subsequent small mixing chamber of an iron pipe with a thin walled silica lining. A three-layer gauze mantle, with the layers separated by means of a $\frac{1}{16}$-in. diam. wire coarse mesh platinum gauze, is also recommended. The catalyst gauze should be of 0.0035-in. diam. wire and 120 mesh in order to secure greatest economy of platinum. The ideal three-layer gauze should utilize a different size mesh and wire diameter in each layer.

An examination of the above brief résumé of the various types of platinum catalysts indicates that a serious state of affairs exists. Everything from preheating to precooling and from one gauze layer to several gauze layers is employed in the commercial projects. Close-contact layers and separated layers have been recommended.

The methods of measuring temperatures, the various types of gas flow meters, and the distinctly great variation in the methods of determining the oxidation efficiencies have made an accurate scientific comparison of the above diverse data a physical impossibility. The writer is making arrangements to compare all of the above types with one standardized set of temperature, gas flow and analytical methods of estimation.

Prior to this exhaustive study it has seemed advisable to discuss some possibilities involved in this oxidation reaction. The choice, design and control of a given form of platinum catalyst must certainly be dependent upon each reaction which must be carried out, and hence a careful study of the theoretical possibilities is distinctly worth while.

Theories of Reactions

The average investigator has accepted the reaction $4NH_3 + 5O_2 = 4NO + 6H_2O$ as the primary step in the oxidation reaction. This attitude has come forth from the fact that as the temperature of the catalyst is above 620 deg. C. the only nitrogen oxide capable of existence at that temperature was NO.

Accordingly, this reaction becomes most interesting when we consider Ostwald's Law of Successive Reactions. It is recognized that whenever a chemical reaction occurs with the possible formation of intermediate compounds, the one involving the smallest loss of free energy will be formed first. Whether the formation of such can be established depends on the stability of the intermediate compound in question.

Kuhlmann originally considered that the basic reaction at the platinum catalyst was essentially

$$2NH_3 + 7O = 2NO_2 + 3H_2O$$

Mendeléeff[2] illustrates a method of producing nitric acid by passing a mixture of ammonia and air over heated spongy platinum. No reactions are written. However, he suggests that ammonia and nitric acid are the extreme compounds of nitrogen with hydrogen and oxygen, and that all the other compounds of these elements may be regarded as intermediate compounds. Mendeléeff[3] considers the following as pos-

[2] Principles of Chemistry, p. 283.
[3] *Ibid.*, page 278.

sibilities when starting with ammonium hydroxide and substituting a hydroxyl:

(1) NH_4OH and abstracting water we get NH_3.

(2) $NH_2(OH)_2$ and abstracting water we get NH_2OH, hydroxylamine.

(3) $NH_2(OH)_3$ and abstracting water we get $NH(OH)_2$, dihydroxylamine.

(4) $NH(OH)_4$ and abstracting water we get $N(OH)_3$, orthonitrous acid.

This is particularly interesting when we note the views which F. Raschig[1] has taken on this matter. He considers that $NO + H_2O$ are not the initial products of the ammonia oxidation reaction, at least in an insufficient supply of oxygen. The reaction is supposed to proceed in a limited supply of oxygen to

$$4NH_3 + 3O_2 = 2N_2 + 6H_2O.$$

However, Müller[2] assumed that NH_3 dissociated into its constituent elements, since he found the gas to consist of 59 per cent N_2 and 41 per cent H_2 at the high temperatures. Raschig considers that di-imide is essentially the first product that is formed in the oxidation reaction. He points out that hydrazine can also form. Mendeléeff pointed out that the formation of hydroxylamine in the previous mentioned work indicated the existence of di-imide and hydrazine. Raschig has considered the reaction in a limited oxygen supply as:

$$2NH_3 + O_2 = N_2H_2 + 2H_2O \quad \text{(chiefly)}$$

and

$$4NH_3 + O_2 = 2N_2H_4 + 2H_2O \quad \text{(in part)}$$

and that it is the di-imide which immediately decomposes into nitrogen and hydrogen and makes it appear that we have

$$4NH_3 + 3O_2 = 2N_2 + 6H_2O.$$

Oesterheld[3] has studied the intermediate stages in the electrolytic oxidation of ammonia, and it was not possible to isolate hydroxylamine. It is interesting to note that the determination of the oxidation potentials confirmed the series of ammonia to hydroxylamine to hyponitrous acid to nitrous acid.

The work on ammonia oxidation involving the use of a multilayer platinum gauze catalyst certainly indicates that the ammonia oxidation reaction is really more intricate than it first appears.

It would appear that the matter of decreased exposed gauze surface might not be the only limitation to a close contact of the layers if we carefully consider all of the possibilities of intermediate compounds. If the initial reaction is not a case of direct formation of nitric oxide, but of some one of the other possible intermediate compounds between NH_3 and HNO_2, then the oxygen requirements at the catalyst surface become quite different. The basic reaction heretofore considered has been

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

and indicates a very high reaction order. The existence of a reaction of the 9th order is quite unlikely, for usually the apparently high order reactions have been reduced to a series of reactions which involve simple interactions. This is unquestionably true in the case at point, but the present uncertainty comes in the choice of these consecutive series of reactions which result in the production of NO from NH_3.

While it is the desire to isolate the exact series of reactions occurring at the surface of the platinum catalyst, it must be realized that the task involves many experimental data. Already there is quite an accumulation of such, yet the facts are inconclusive. A continued study of the absorption spectra may clear up the uncertainties.

The combustion of carbon has created much discussion, and even today the ultimate decision is uncertain. While Dixon, Strange and Graham[7] consider the formation of CO as the initial product, yet we find Haber[8] concludes that the initial reaction is the direct formation of CO_2. Rhead and Wheeler[9] have concluded that there is a simultaneous formation of CO and CO_2. The theoretical equilibrium indicates that carbon monoxide must be the chief constituent above 800 deg. C., and yet the evidence points to at least some dioxide. The initial formation of nitrogen peroxide rather than nitric oxide in the ammonia oxidation reaction would certainly be an important factor in the catalyst spacing relations. While the analogy to the ammonia oxidation reaction may not be completely well founded, yet it serves to show that it will be easy to develop a variety of opinions relative to this.

At one period of the past investigations, the qualitative indications were exceedingly strongly in favor of an opinion that the initial step of the oxidation reaction demanded a much larger oxygen concentration than that corresponding to the formation of nitric oxide. If such ultimately proves to be the case, the spacings between the gauze layers will demand a careful adjustment of the space-time-temperature-oxygen interdependencies.

Spacing of Gauzes

If the initial step of the oxidation reaction involves excessive amounts of oxygen, then the relationship of gas space between the catalyst layers becomes one of the greatest importance. However, this feature is important even without this oxygen factor directly entering the consideration.

The use of a single layer of platinum gauze with 0.0025 to 0.003 in. diameter wire and 80 mesh as a catalyst appears to be rather popular in the various above-mentioned systems. Since the reaction is essentially a contact process, it seems absurd that the use of much smaller free spaces between the wires of the gauze have not been adopted. From the standpoint of economy of platinum a single gauze of 0.0025 in. diameter wire and from 120 to 150 mesh is more desirable.

The function of a second or third gauze layer can be attributed to the blocking of the gas spaces of the first layer. However, if the only service which a second layer of a platinum gauze catalyst performs is one of "cleaning up" the spare ammonia molecules which pass through the interstices of the first layer, then the use of more than a two-layer gauze catalyst is probably distinctly uneconomical from the standpoint of platinum consumption.

The Bureau of Mines work involved the use of a four-layer catalyst for the purposes of heat conservation. An eight-layer catalyst has been recommended. The heat conservation argument cannot be real unless the four-layer catalyst will oxidize essentially four

[1] *Z. Phys. Chem.*, p. 138, 1918.
[2] *Z. Phys. Chem.*, p. 169, 1913.
[3] *Z. Anorg. Chem.*, vol. 86, p. 105; 1914.
[7] *J. Chem Soc.*, vol. 59, p. 759; 1896.
[8] Thermo. of Tech. Gas Reaction, p. 255.
[9] *J. Chem. Soc.*, vol. 101, p. 846; 1912.

times the quantity of ammonia per unit time and unit inner layer exposed surface of a single-layer catalyst. Even then, the heat conservation will only be that equivalent to the small conduction and radiation losses. If a suitable heat exchanger is employed, this heat conservation argument becomes negligible and the economical use of the platinum becomes the real issue. In other words, are more than two layers of a platinum gauze catalyst justified? The answer is certainly dependent upon the function of the catalyst, and the function of the catalyst governs in part the spacing arrangement of these two layers. Of course it is impossible to make absolute contact of one layer to the other, and it is also impractical to block up an excessively large amount of the upper surface of the second layer by the protecting under surface of the first gauze layer.

Effect of Voids Between Separated Catalyst Layers

The effect of a void heated space between the possible separated layers must be considered, even if the initial oxidation reaction goes to NO. It is quite clear that the thickness of this space must essentially be dependent upon the velocity and temperature of the gas mixture. While Landis[10] has considered that the oncoming ammonia-air mixture would be decomposed by the radiated heat from a hot gauze, such a state of affairs seems impossible. The gas cannot be heated in this manner, although convection currents may play some part. We do know that if the gas becomes heated through conduction, or by contact with the first layer of the catalyst, or through a properly designed heat exchanger, after a sufficient time the reaction $4NH_3 + 3O_2 = 2N_2 + 6H_2O$ will occur. The burning of ammonia in air is an old time experiment and involves no catalyst whatsoever.

The work of Jellinek[11] upon the nitric oxide equilibrium has shown that nitric oxide can be catalytically decomposed to nitrogen and oxygen, yet this is a matter of temperature-time-catalyst. It is also true that the velocity of dissociation of nitric acid, in the absence of a catalyst, is dependent upon the temperature. The reaction $2NO \rightarrow N_2 + O_2$ in the absence of a catalyst may account for the slow decomposition of some of the combined nitrogen only when a temperature of 827 deg. C. is attained. While NO is unstable below 1227 deg. C., yet the velocity of the decomposition reaction is distinctly slow. The partial pressure of the NO is small and the time short. Hence, it will be difficult to realize that much trouble should be encountered by this reaction in the space between the two gauze layers at the gas velocities generally employed.

Interaction of Ammonia With Nitric Oxide

Another possible source of trouble might involve the interaction of ammonia with nitric oxide. The reaction $4NH_3 + 6NO = 5N_2 + 6H_2O$ has been considered by Reinders and Cats[12]. This reaction has also been studied by Baxter and Hickey[13] in reference to a possible method for the production of pure nitrogen. Reinders and Cats state that the double decomposition reaction of NH_3 and NO can take place without a catalyzer. Experiments were conducted by them with 5 per cent NH_3 mixtures in air and with a 10 : 1 ratio of NO : NH_3. The studies were only qualitative, yet it was observed that the reaction without catalyzer, or in porcelain, proceeded slowly, while with platinum the reaction was greatly increased. However, it was noted that the relative influence of platinum upon the reactions involving the oxidation of ammonia to nitric oxide and that involving the double decomposition were quite different. The influence of the platinum catalyst upon the reaction velocity of the nitric oxide formation was much greater than on the double decomposition reaction. This relative influence of the catalyst is probably a very important factor in these reactions. Recent qualitative work has indicated that, in the absence of a catalyst, this reaction depends much upon the time-temperature factors and that it can be made small compared to the nitric oxide formation reaction at the catalyst surface. However, a certain amount of care must be exercised to prevent this reaction from assuming an important position.

Influence of Space-Time-Temperature Conditions

All of the above-mentioned decomposition reactions are dependent upon the gas velocity, or the space-time relationships. It would seem as if the spacing between the layers should then depend quite entirely upon the space-time-temperature conditions. It is surely advisable to determine these relationships for any specific commercial type of apparatus that is being utilized, and then adjust the spacings between the gauze layers in accordance with the requirements.

The writer is convinced that the close contact of gauze layers involves an unnecessary amount of protected platinum surface and is to be avoided.

The importance of the spacings between the gauze layers was clearly demonstrated in some preliminary work which was under the direction of the writer for the nitrate division of the Ordnance Department. Lieut. George Cawley originally began the study of this separated gauze layer problem because of observations made upon layers which were not in close contact with each other. It was noted that the points of the second layer, where there was contact or where small gaps existed between the gauze layers, showed the maximum amount of activation or sprouting. The activation of the lower layers in close contact to the upper has always been observed to be a very slow process. The spacing greatly facilitates this activation.

A continued study by the writer has shown that the capacities of two gauzes can be greatly increased, on a non-preheated gas mixture, by a proper spacing of the layers over that where close contact is employed. The reason for this increase is due, in part, to the greater available platinum surface exposed to the gas, but the more important feature is involved in the temperature-reaction velocity relationships within the gas system. When passing a cold ammonia-air mixture to a platinum gauze, a portion of the gas does not come in contact with the platinum surface of the first layer, but passes through the spaces of the mesh. The amount of ammonia passing these gaps depends upon the gas velocity.

Table I gives a fair approximation of the quantity of ammonia passing through the spaces of a single electrically heated gauze of 0.0026-in. diameter wire at

[10] Chem. & Met. Eng., vol. 20, p. 472; 1919.
[11] *Z. Anorg. Chem.*, vol. 49, p. 229; 1906.
[12] *Chem. Weekblad*, vol. 9, p. 47, 1912.
[13] *Am. Chem. J.*, vol. 33, p. 300; 1905.

80 mesh, provided we take into consideration that the decrease in oxidation efficiency is due to excessive gas velocity and a resultant passage of ammonia past the catalyst.

TABLE I.

Lb. NH_3 Per Oz. Pt Per Min.	Per Cent Eff.	Lb. NH_3 Per Oz. Pt Per Min.	Per Cent Eff.
0.025	95	0.095	80
0.035	93	0.120	76
0.045	90	0.145	70
0.060	86	0.190	62

It is evident that an increase of fivefold above a very low normal quantity of ammonia in unit time only decreased the oxidation efficiency approximately from 95 to 76 per cent. In other words, with a fivefold increase in the work thrust upon the first layer of a 0.0026-in. diameter wire and 80-mesh gauze we find it will still do 76 per cent of the work. This means that the concentration of ammonia in the gas escaping the first layer is exceedingly small, yet the excess of oxygen must also be small. The oxidation reaction develops so much heat that the expansion of the gases, by the increased temperature, must also be considered in this diluting effect. The greatly reduced concentration of ammonia indicates also a decreased reaction velocity, and the only means of speeding up the so-called "pick-up" reaction of a second gauze layer must be by a decided increase in the temperature of the ammonia-oxygen molecules of the gas phase. Since those molecules of ammonia which pass the gauze do not presumably make contact with the hot platinum, the only method of increasing their temperature is through conduction and convection. Closely connected gauze layers will not give sufficient time for the heating of the ammonia molecules to a temperature sufficiently high for the desired increased reaction velocity in the weak gas mixture for the available catalyst contract period. The hot gases from the reaction of the oxidation of the initial 76 per cent will transfer the necessary heat to the ammonia-air mixture which has passed the gas for the first layer, provided sufficient time is obtained. The simplest answer to this is by the use of a gas space between the layers. This space must be of sufficient depth to permit the ammonia-oxygen molecules to attain a temperature sufficiently high for a high reaction velocity when they next meet a catalyst surface. The limiting depth is that where the time-temperature conditions permit the reaction to proceed to the non-catalytic

$$4NH_3 + 3O_2 = 2N_2 + 6H_2O.$$

The interaction of nitric oxide with ammonia, as studied by Baxter and Hickey,[14] upon the preparation of nitrogen from the reaction

$$6NO + 4NH_3 = 5N_2 + 6H_2O$$

showed that the reaction was complete only when the mixture was heated to a high temperature in the presence of a catalyst (such as platinum). Fortunately, the actual relative rate at which this reaction occurs under the same conditions as the nitric oxide formation reaction is most favorable to the nitric oxide production even in the presence of a catalyst.

Since the "clean up" reaction involves a dilute ammonia gas mixture, the heat of reaction upon the second catalyst surface will be much lower than that of the first layer. In an effort to equalize the temperatures on the different layers the writer has used a coarse-meshed heat-conducting gauze. This must be fabricated of metals which do not destructively decompose dilute ammonia-oxygen mixtures or nitric oxide. A quarter-inch mesh platinum gauze has served excellently in this work. Such a metallic gauze layer separator permits the surplus ammonia molecules to be heated to a higher temperature than those of the intake gas and maintains a high catalyst temperature on the succeeding layer. Thus the reaction velocity can be increased to a point where the active surface of the under gauze layer will do its proportionate share of the work even when the first layer is subjected to a quantity of gas eight times its normal. The metallic coarse-meshed separator also enables the spacings between gauze layers to be maintained quite uniform.

The economical use of a two or three layer gauze involves the utilization of a high temperature of reaction within the gas phase and hence a preheated intake mixture. It also necessitates the use of exceedingly short periods of contact within the catalyst zone, in order to prevent undue decomposition reactions at the elevated temperatures.

Summary

This discussion of the factors affecting the design of ammonia oxidation apparatus may be summarized briefly as follows:

1. There are as many different commercial ammonia oxidation platinum catalyst installations as there are possible types.

2. The use of a suitably preheated air-ammonia mixture is pointed out as most important for the production of a sufficiently high temperature for a rapid reaction velocity of the desired reaction.

3. The use of a platinum gauze of 0.0025 in. diameter wire and 120 to 150 mesh is far more logical than one of 80 mesh, since it decreases the free gas space between the wires.

4. A three-layer platinum gauze arrangement represents probably the maximum upper limit of gauzes, if the economical use of platinum is considered. A mantle form of catalyst is desirable.

5. The gauze layers should be separated a sufficient distance in order to permit the much diluted ammonia-air mixture, which passes the first layer, to become raised to a higher temperature than the original more concentrated ammonia mixture. An increased reaction velocity may thus be obtained. A coarse-meshed platinum separator has been suggested as a means of maintaining uniformity of gas space and equality of temperature in the various layers. The temperature of the last layer will always tend to be much lower than the others unless a heat-conducting separator is utilized.

6. It is quite probable that NO is not the initial product formed in the ammonia oxidation reaction. If such is the case, the use of separated gauze layers will depend upon a careful application of space-time-temperature-oxygen factors.

7. The troublesome factors involved in the theoretical decomposition reactions when using separated gauze layers can be made to vanish by a proper control of the space-time-temperature factors.

[14] *Am. Chem. J.*, vol. 33, p. 300; 1905.

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Electric-Resistance Furnace of Large Capacity for Zinc Ores
II. Operation of Furnaces and Characteristics of Process

Details of the Experimentation Work With Electric-Resistance Furnaces of Commercial Size Based on the Author's Well-Known Plan of Making Briquets With the Zinc Ore to Be Treated and Using These Briquets as Resistors for an Electric Furnace*

BY CHARLES H. FULTON

OPERATION OF FURNACE C

IN SETTING up a charge, a 0.75-in. graphite disk, the diameter of the briquet, was placed on the graphite block *a*, Fig. 1,† and thinly coated with contact material, then the first briquet placed in position, its top coated with contact material, then the next briquet was placed in position and its top coated, then the third. This last briquet had a 2-in. hole at the center 2.5 in. deep which was formed at the time of pressing the briquet by the top pressure plate, which was fitted with a slightly tapered pin. After the twelve briquet columns were placed in position, 1.75-in. graphite pins were dropped in place in the top briquet, contact material applied, and 1-in. graphite disks, with a 2-in. hole at the centers, slipped into place, and the top connectors placed into position. The top connectors, 5 in. thick, were provided with tapered holes somewhat larger than the pins, into which the projecting pins fitted. The space between the pins and the walls of the holes in the connectors was filled with finely crushed coke. By this system the briquet columns were held firmly in position and the slight shrinkage and motion in the charge provided for.

A charge was set up in from 2 to 3 hr. by two men. In the making of the briquets care was taken to have their ends parallel and perpendicular to the axis, and all approximately of the same length. The length sometimes varied slightly, in which case and when briquets broken in the handling were used, deficient height of column was made up by the use of extra graphite disks.

After the charge was set up, a fireclay luting was spread, ring form, on the base and the retort was lowered into position by the crane. The luting made a tight joint. The exit hole at the top of the retort was left open for a short time after power was applied at the electrodes, to permit the escape of pitch fumes and the first gases, after which it was closed, and the valve *X* (Fig. 4), leading to the vapor box and condenser, opened.

In Fig. 6, the passage from the base to the upper chamber of the vapor box *v*, Fig. 4, is shown in *b*. From the vapor box, the gases passed to the central condensing chamber *p* of the condenser, thence by the cross passage *k* to the outer annular condensing chamber, which was divided, by vertical walls, into four compartments in series, the carbon monoxide finally burning at an exit at the top of the last one.

The central condensing chamber drained into the vapor box, and spelter in furnace C was tapped from the vapor boxes. In the operation of this furnace, practically nothing was found in the annular condensing chamber except a very small quantity of blue powder. This chamber was provided with tap holes at the bottom. The retort ends of this furnace were satisfactory, but the condenser was too complicated. The condensation was excellent as regards the nonformation of blue powder. After six charges, the condenser was found to be practically free from blue powder and dross. At no time did the gas flame show more than the permissible amount of zinc. Some zinc was lost by leakage at the cross passage from the central to the annular chamber, which could not be kept tight. The bottom of the vapor boxes also could not be kept tight, and spelter escaped in considerable quantity into the base and ground beneath the base. It was decided that the condenser would have to be a simpler structure and that the passage from the retort to the condenser must be simple, short, and easy of access for the purposes of cleaning. The new design gave rise to furnace D.

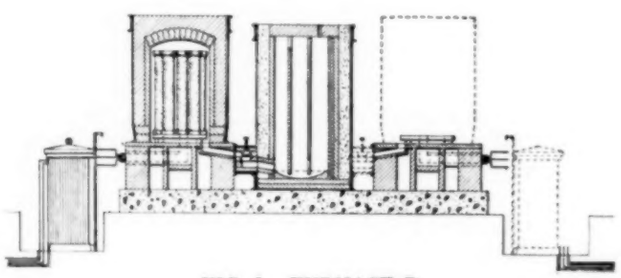


FIG. 8. FURNACE D

FURNACE D

This furnace differs from furnace C in the design of the condenser. The same principle was used, but there was no heating of the retort base or the condenser. Fig. 8 illustrates the arrangement. Instead of a bottom connection from the retort base to the condenser, a top connection, shown in Fig. 9, was permanently attached to the condenser.

After the retort was placed in position, the condenser was lifted by the crane and swung into position so that the opening of the connection registered with the opening in the top of the retort. Luting was then placed around the retort opening and the condenser gently lowered to its base; this made a tight joint between the condenser and retort. When the charge was distilled, the transformer was transferred by a crane to the second retort base, the valve of the condenser connection closed, and the condenser lifted by the crane, swung around 180 deg., and set on the center of its base. The retort was then lifted about 3 in. and pulled toward the center of the building; this swept the dis-

*For Part I, describing the furnaces and process, see CHEM. & MET. ENG., vol. 22, No. 2, pp. 73-79, Jan. 14, 1920.

†See CHEM. & MET. ENG., Jan. 14, 1920, p. 73.

tilled briquets to the floor over an apron plate. The retort was then transferred to the other charge, the condenser set by the crane, and distillation begun on the second charge. A new charge was set up on the first base, the men being protected from the hot base by asbestos mats and shoes.

The connection was designed so that it could be readily cleaned out by the removal of the cover-plate over the graphite plug valve. The connector is by no means a perfect device and had to be cleaned every second charge, especially if the valve was not carefully closed at the end of the run. The passages also are somewhat small.

CONDENSER

The condenser was made of the same shell as used in furnace C, except that a steel bottom was riveted in place. It was lined first with 9-in. sil-o-cel brick followed by 4.5-in. of high-grade firebrick. Its interior diameter was 42 in. and its interior height 9 ft. It had a longitudinal partition of firebrick wall, as shown in Fig. 8, and was known as a two-pass condenser. For the initial charge, the condenser was heated by an oil burner placed into an opening at the top, the products of combustion traveling down the large pass, up the small pass, and out of the connection as a flue. Preliminary tests showed that if the condenser was heated to 940 deg. C. and then closed and allowed to stand the temperature dropped from 940 to 630 deg. C. in 16 hr. It was later found that this radiation about balanced the heat input, due to the condensation of zinc vapor, and the condenser maintained itself at a temperature of about 700 deg. C. at the inlet and 500 deg. C. at the exit. With more rapid working, it would probably have been necessary to spray the exterior with water. With less rapid working the condenser would undercool, as was the case when less than two charges were distilled in 24 hours.

Charges 7, 8, 9, 10, and 11 were distilled with this

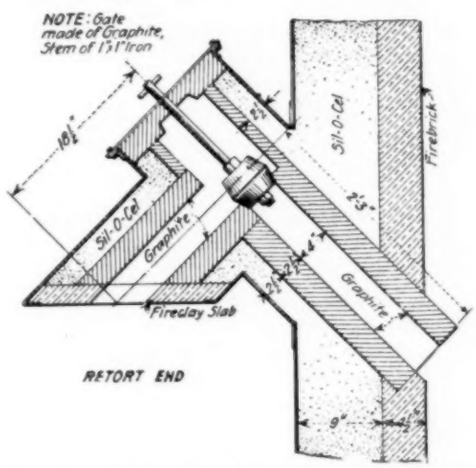


FIG. 9. TOP CONNECTION FOR ELECTRIC FURNACE

condenser, when the bridge wall collapsed at the top, at which point the temperature was about 500 deg. C. This collapse was due to carbon deposition within the firebrick localized at the iron-oxide spots of the brick. The action is due to the decomposition of carbon monoxide at the temperature existing and is elsewhere described.[4] The condenser was then repaired, the bridge

[4] C. H. Fulton, "Condensation of Zinc From Its Vapor." Bulletin 140, A. I. M. E., (August, 1918).

TABLE II. METAL BALANCE

Runs Nos. 7, 8, 9, 10, and 11, May, 1917

Zinc in Baked Briquets	Lb.
Each charge	573.0
Zinc in five charges, total charged	2855.0
Zinc remaining in Distilled Briquets	
Run No. 1, 2.36 per cent	52.4
Run No. 2, 0.67 per cent	14.0
Run No. 3, 1.80 per cent	39.0
Run No. 4, 0.93 per cent	19.4
Run No. 5, 5.97 per cent	151.0
Total Zinc in Distilled Briquets	275.8
Zinc cast as spelter	1242.5
Zinc in scrapings from bridge wall, rechargeable @ 41.75 per cent zinc	899.0
Zinc in brick from condenser, @ 1.74 per cent zinc	115.3
Zinc unaccounted for	322.4

Summary

	Per Cent	Lb.
Spelter tapped	42.7	1242.5
Scrapings, rechargeable	30.8	899.0
Zinc in brick from condenser	3.9	115.3
Zinc in distilled briquets	9.1[a]	275.8
Unaccounted for	13.5[b]	322.4
	100.0	2855.0

[a] The amount of zinc left in briquets is entirely at the will of the operator; this is shown on the individual runs. The runs in this series were, in part, undertaken to obtain figures on power consumption, and certain runs were discontinued at given power inputs to determine proper point of stopping.

[b] This covers zinc absorption in retort hood base, and passageways, and includes zinc escaping uncondensed.

wall being replaced by a 30-in. cylindrical flue tile, for a second pass. The condenser was again brought to the desired temperature by the oil burner and charges 12, 13, and 14 run, when part of the condenser brickwork, including the top tile, collapsed for the same reason as before.

The condenser, when opened after each run, showed no blue powder, and the walls were covered with spelter in the form of droplets. There was some zinc dross in the bottom. The complete metal balance of these two runs is given in Tables II and III. In the first run 42.7 per cent of the zinc content of the charges was recovered as cast spelter bars; and in the second run 52.6 per cent. This recovery was from a practically new furnace in each instance.

The destruction of the condenser lining also took place with furnace E. It became evident, therefore, that the condenser lining would have to be made of refractory material free from iron. The only real difficulty in the condensation was the destruction of this lining at a temperature of about 500 deg. C. At higher temperatures the destruction is not noticeable, as the condenser failed only in the parts where this temperature existed. In the retort, lined with the same firebrick, no destructive action was noted; in fact, the retort lining was not repaired at any time that the plant was in operation. It is probably not possible to operate any large zinc condenser for a long period, even though every precaution is taken in construction and operation to keep it tight against air. One of the underlying ideas in a condenser of this movable type is to operate it as long as it is in good condition, then replace it with another one at the proper temperature and clean and reheat the first one.

TYPICAL ELECTRICAL RECORD OF RUN

In Table III is given the electrical record of run 14, which is typical. It will be noted that the balance of the phases is good; in many runs it was still more even. The power factor ranges between 88 and 91. The total time was 15.5 hr. The average input was 143 kw., which is too low, but all that was available. The power consumption was 2109 kw.-hr. for the charge, which is equal to 2576 kw.-hr. per ton of ore. This is higher than necessary, as later work demonstrated.

TABLE III. ELECTRICAL RECORDS OF RUN 14

Time	Electrode Volts Per Phase 1-2	2-3	3-1	Primary Volts Per Phase 1-2	2-3	3-1	Primary Amperes Per Phase 1	2	3	Indicating Wattmeter		R.W.H.M.a	Pyrometer Reading, Degrees C. Retort Bottom 1	Retort Top 2	Condenser Top 4	Condenser Bottom 5	
6:15	290	290	290	290	290	290	150	150	100	...	...	1508.0	...	...	...	...	In at 5:50 a.m., 220 volt. connection.
7:00	121	118	132	126	126	130	480	425	260	...	...	1510.5	...	...	...	...	
7:30	117	112	120	120	122	122	590	540	460	...	...	1512.0	...	...	...	...	
8:30	134	131	132	271	256	266	445	430	375	255	225	1513.0	480	640	650	520	
9:00	67	64	65	138	124	128	280	310	300	80	90	1515.0	460	650	630	520	
9:30	96	86	93	196	181	192	615	615	615	255	255	1517.0	500	670	610	560	Flame lit at condenser.
10:00	79	72	75	162	150	158	650	650	660	215	230	1520.0	520	680	610	585	
10:30	68	65	65	142	134	134	650	595	660	175	200	1522.0	530	690	660	610	
11:00	62	59	60	130	124	124	650	600	650	165	185	1525.0	540	690	670	600	
11:30	63	60	59	130	124	122	645	550	650	150	180	1527.0	550	710	670	590	
12:00	63	58	61	132	128	126	650	600	655	165	190	1529.0	570	730	670	590	
12:30	65	61	62	136	128	128	680	620	680	175	195	1531.0	570	730	...	...	
1:00	65	61	61	134	128	126	655	595	665	165	180	1534.0	550	720	...	...	
1:30	67	62	63	139	130	128	680	620	650	170	180	1536.0	520	680	...	...	
2:00	64	61	62	134	128	128	635	580	640	165	185	1538.0	490	670	...	...	
2:30	65	61	62	126	128	128	620	565	620	165	180	1541.0	490	660	...	...	
3:00	65	60	62	134	128	128	620	600	620	165	175	1543.0	775	920	...	470	
3:30	66	61	63	140	130	130	590	600	610	160	180	1545.0	780	930	...	470	
4:00	66	62	65	140	130	130	570	600	620	160	180	1547.0	780	940	...	480	
4:30	65	62	63	140	130	130	610	570	610	170	160	1549.0	790	960	...	480	
5:00	69	67	65	142	138	136	590	490	610	150	180	1552.0	800	970	...	480	
5:30	67	65	65	140	136	170	600	520	600	155	180	1554.0	800	990	...	480	
6:00	68	65	65	140	138	138	600	520	600	160	175	1556.0	820	1010	...	490	
6:30	69	67	65	140	138	136	590	550	590	155	175	1558.0	840	1030	...	490	
7:00	70	67	67	144	140	138	600	520	600	165	188	1560.0	850	1045	...	488	
7:30	73	70	71	154	146	144	620	550	620	180	200	1562.0	860	1060	...	490	
8:00	74	71	71	152	143	146	620	520	600	175	190	1565.0	875	1085	...	480	
8:30	74	70	70	152	144	144	600	560	590	165	185	1567.0	900	1110	...	470	
9:00	74	69	71	150	142	144	600	560	580	180	185	1570.0	920	1130	...	470	Power off at 9:10.
9:45	75	70	72	152	144	144	560	530	560	175	180	1571.0	935	1110	...	470	Power on at 9:45. Power off at 9:50.

a Recording watt-hour-meter. For kw.-hr. multiply by 33⅓.

As charge 14 was the last of a run, it was allowed to cool with the retort in place, and the briquets of every other column weighed, sampled and analyzed. The record is as follows:

Twelve columns of briquets, three each. Total height of all columns, 763 in. Weight of undistilled charge 3161 lb. Density of baked briquets, 4.15 lb. per lin.in. Density of distilled briquets, 2.82 lb. per in. Baked briquets contained 18.2 per cent zinc. Total zinc in charge, 573 lb. Total zinc in distilled charge, 0.131 per cent, or 2.6 lb. Weight of ore in charge, 1630 lb.

The density of the briquet is a measure of the distillation. The above charge lost 32 per cent of its weight; this is the proper loss for complete distillation, with the briquets used, and made of 100 parts Missouri silicate ore, 35.5 per cent zinc, 85 parts coke, and 18.5 parts pitch. A loss of 34 to 40 per cent may take place when the charge is overdistilled, in which cases only traces of zinc can be detected in the distilled briquets. In Fig. 3 are shown the resistivity curves of charges 8, 13 and 14; these are typical of briquets made of Missouri silicate ore. Toward the end of the operation the resistivity rises somewhat; and this rise, indicated at the instrument board as a drop in amperage with no voltage change made, indicates the end of the distillation period.

The distilled charge was discharged from the retort base by slightly lifting the retort and then pulling it sidewise by means of the crane. The bottom graphite electrode blocks stay in place, but the top ones are, of course, swept off with the charge. They are at once drawn from the mass of briquets and covered with crushed coke. Graphite does not oxidize readily at a low red heat, and there was very little wear on the connector blocks during the operation of the plant. The bottom blocks on the base, immediately after the discharge of the briquets, were thinly covered with crushed coke, spread by a big shovel. After an hour the base cooled to or below a dull red, when it was cleaned off by a stiff broom and new charge set up. The discharged briquets on the floor were quenched with water and then removed. With furnace F, the base was higher and the briquets were discharged directly into a steel car, quenched, and removed to the dump.

Connectors Made of Briquet Mixture

Experiments have been made with a small-scale laboratory distilling furnace, with 1¾-in. diameter briquets, in which the graphite connectors were replaced by connectors molded from briquet mixture, modified by the addition of somewhat more pitch and the use of finer coke to give additional strength. These experiments were successful and it was the intention to make full-size connectors of this type, when the work had to be discontinued. Both bottom and top connectors of this kind were to be employed, thus increasing the capacity of the retort, and doing away with the use of all graphite except the electrodes proper, which are not subject to wear. It will be noted that even with the use of graphite connector blocks, there is no regular or fixed electrode consumption in this furnace.

Use of Distilled Briquets

The distilled briquets may be used again as coke. In the briquet charges distilled in furnace F, some of the briquets were made by replacing 50 per cent of the coke by 70 per cent of distilled briquet. These caused no difficulty in the distillation, although the distilled briquets are a most unfavorable material on account of the very high percentage of residue in the ore. The distilled briquet is practically a coke containing 34.5 per cent ash, which high ash content would not be present with ordinary zinc ores in the briquet.

Furnace E

Furnace E differs from furnace D in having a bottom connection between the retort base and the condenser, this connection being part of the condenser. In order to arrange for this construction, the central part of the furnace base, which had served as a condenser support, was removed and the old passageway for zinc vapor in the retort base rebuilt. Grooves were also cut in the retort base immediately around the graphite base blocks, which drained into the vapor passage. It

was thought, in the operation of furnace D, that in the earlier stages of the operation metal sometimes condensed on the walls of the retort and drained to the base, giving rise to redistillation, which prolonged the time and increased power consumption. The results obtained with furnace E do not prove this to be true. From the construction standpoint, however, there are certain advantages in a bottom connection.

In the operation of the process, the retort from a distilled charge is usually between 1100 and 1200 deg. C., but sometimes cooler. The ideal condition for operation is one in which the retort wall temperature is always higher than the charge temperature, which can be obtained by working with good hot retorts and by rapid distillation.

Furnace E is shown in Fig. 10. It was operated in the same manner as furnace D and the results with it were about the same. The condenser was a three-pass one, the passes being made of flue tile, as shown. After nine charges, the condenser broke down in the same way as the furnace D. No metal balance was

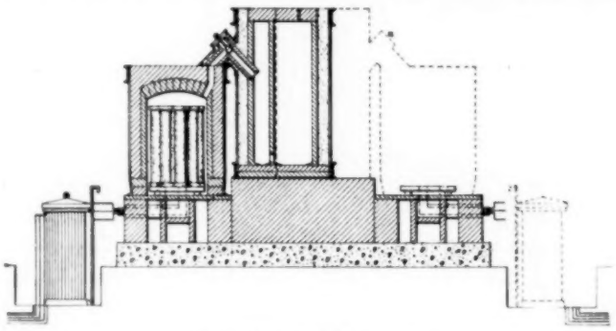


FIG. 10. FURNACE E

drawn up on this run. About 60 per cent of the zinc in the charges was recovered as cast spelter, over 1100 lb. being drawn from the condenser at one tap. When the condenser was opened, the walls were heavily coated with metal drops, dross, and dense rock oxide, and there was considerable dross in the bottom, but no blue powder. Once or twice during the campaign, the condenser valve was opened during the change from base to base and air passed through the condenser, a highly undesirable condition.

Furnace F

Furnace F was the furnace constructed for operation in connection with the new electrical equipment, consisting of three 870-k.v.a., single-phase transformers, switch connections and instrument equipment. The furnace consisted of three adjoining retort bases, two distilling retorts (identical with those used for the former furnaces), a movable combination condenser for spelter, blue powder, and oxide, and one of the old retort bases reconstructed to preheat retorts by means of oil burners. The electrical equipment was designed for extra capacity, so that it could be used in proposed subsequent work on larger units with 12-in. briquets. The foundation of the bases was built of concrete and contained a tunnel for the bus-bars from the transformers. The transformers were set as close as possible to one end of the furnace, in a shallow pit, which had waste connections to take care of the cooling water. The bases proper consisted of rectangular steel boxes filled with a firebrick arch, containing the opening for the electrodes and, on one side, a vapor passage leading to the condenser connection.

The idea was to have the extra bases form the top of the cars on which the charge of raw briquets would be set up, with the connectors in place. These cars would then be passed into the ovens and, after baking, removed, and the base with its charge picked up by crane and set on the furnace heated to a temperature of 500 to 600 deg. C. and at once distilled, thus conserving the heat energy in the hot baked charge. The movable base also served as a cover for a flue system under the base and surrounding the electrodes, which was heated by an oil burner located on the opposite side to the vapor passage. The exit flue from this system emerged from each base below the vapor passage and the products of combustion were passed to a heating chamber in the spelter condenser, to preheat this for the start of operations. This base-heating system was, in effect, the same as was used in furnace C. It was found to warp the bases and to be unnecessary, as in the case of furnace C, and was not used in subsequent operations. The electrodes were 12 in. in diameter, supported on jacks in the tunnel underneath the bases, and passed through the openings in the base, the seal between the electrodes and the openings being made by crushed carbon. The jacks afforded a ready means for slightly raising or lowering the electrode to keep it level with the top of the base. Fig. 11 shows the construction of furnace F.

The condenser proved unsatisfactory, so it was replaced with the style used on furnaces D and E. Experiments in making of zinc dust were successful, but the experiments in making oxides failed in the collecting device used. Before the spelter condenser could be again used the war conditions stopped experimental work.

The electrical system was such that the primary leads to the transformers could be connected either in delta or in Y, and the secondary leads could be brought out either in delta or in Y connection. By means of switches on the primary side, a wide range of voltage by small steps could be obtained at the electrodes. The current used was 40-cycle 13,000 volts primary, from Keokuk dam on the Mississippi River. Fig. 12 shows the wiring diagram of the three single-phase 870-k.v.a. transformers, the various connections of switches, the k.v.a. capacity of the transformers obtainable with the different connections, and the corresponding voltage at the electrodes of the furnace.

Operating With Preheated Retorts

In the furnace as at first operated, in the initial charge of any run, the retort was heated by radiation from the briquet charge, and when transferred after

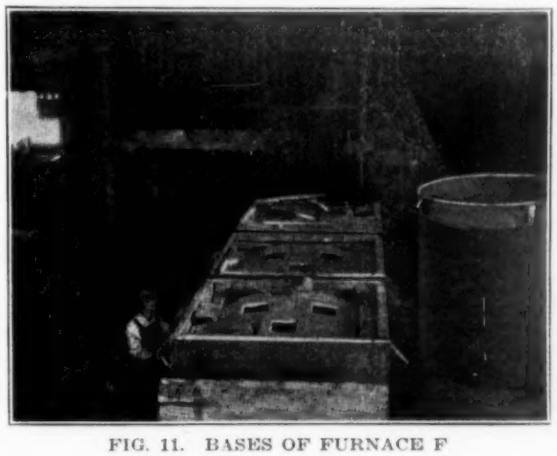


FIG. 11. BASES OF FURNACE F

the distillation to the second charge was at a temperature of from 1000 to 1200 deg. C. The initial charge therefore always showed the extra power consumption necessary to heat the retort to this temperature. The ideal condition is to have the heat radiated from the retort walls to the charge rather than from the charge to the retort, which means working with hot retorts. In the case of high cost of electrical energy, the process lends itself readily to a method of working in which the retort is preheated to a temperature of 1250 to 1350 deg. C. by means of a regenerative system of preheating bases fired by gas. The use of the preheated retort reduces the time and power consumption. To the electrical power consumption in this case must, of course, be added the cost of preheating; but the electrical power consumption will be reduced by virtue of the shortened time, as this cuts down the radiation losses. In the operation of furnace F, preheated retorts were used. One of the old furnace bases was arranged for this work, the retorts being preheated by oil. In Table IV are given the results obtained.

The method adopted was as follows: A retort would be heated and then placed on the cold briquet charge, a second retort meanwhile being heated on the heating base; when this second base had attained a temperature of say 1200 deg. C., the first retort would be lifted from the charge and replaced on the heating base after the second retort was placed on the briquets; this operation was repeated until the charge was at a distilling temperature, namely 950 to 1000 deg. C.

By comparing the temperature figures, it was noted that the radiation from the retort is not rapid. The normal preheating period was 2 to 3 hr., and to obtain the total time of a charge on the base this must be added to the "Time of Distillation" given in Table IV. Under normal rapid and continuous working from base to base on the furnace, the hot retort from a finished charge would be set on a new charge, allowed to remain about 1 hr., and then replaced by a retort at 1300 to 1350 deg. C. from the heating base, and the retort just taken from the charge put on the heating base. After the second retort was on the charge about 1 hr., electrical distillation would be commenced. It need not be especially pointed out that power consumption will be lowest with such rapid and continuous working. Power consumption figures are given in Table V.

The theoretical power consumption for 60 per cent zinc ore containing 20 per cent siliceous residue, made into briquets containing 100 parts ore, 70 parts coke, and 17 parts coke pitch, is 1372 kw.-hr. exclusive of radiation losses. Of this, 421 kw.-hr., the amount required to preheat the charge to 920 deg. C., may be obtained by non-electrical means, as by preheated retorts. The carbon monoxide, which in this large-scale work may be collected, amounts to about 7200 cu.ft. per ton of ore, which at 35 cu.ft. per hp.-hr. is equivalent to 206 hp.-hr., or 154 kw.-hr. The energy in the briquet residue, in cooling from 1200 to 25 deg. C. is equal to 378 kw.-hr. Some of this may perhaps be recovered. The radiation losses can be made very

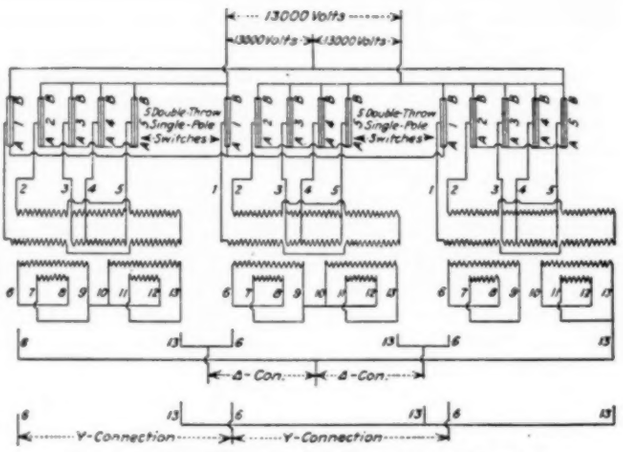


FIG. 12. WIRING DIAGRAM. 870 DEG. K.V.A. TRANSFORMERS

HIGH-VOLTAGE COILS, DELTA CONNECTIONS

K.v.a.	Connections	Voltage of Secondary Coils, Delta Connection	Voltage of Series-multiple Coils, Y Connection
495	2 to A, 3 to A, 1 to B & 5 to B	99	171
530	2 to A, 4 to A, 1 to B & 5 to B	106	184
580	2 to A, 3 to A, 1 to B & 4 to B	116	200
640	2 to B, 3 to B & 1 to B	128	222
695	2 to A, 4 to A 1 to B & 3 to B	139	240
770	2 to A, 5 to A, 1 to B & 4 to B	154	266
870	2 to A, 5 to A, 1 to B & 3 to B	174	302

HIGH-VOLTAGE COILS, Y CONNECTIONS

K.v.a.	Connections	Voltage of Secondary Coils, Delta Connection	Voltage of Series-multiple Coils, Y Connection
286	2 to A, 3 to A, 1 to A & 5 to B	57	99
306	2 to A, 4 to A, 1 to A & 5 to B	61	106
335	2 to A, 3 to A, 1 to A & 4 to B	67	116
370	2 to B, 3 to B, 1 to A	74	128
400	2 to A, 4 to A, 1 to A & 3 to B	80	139
445	2 to A, 5 to A, 1 to A & 4 to B	89	154
500	2 to A, 5 to A, 1 to A & 3 to B	100	174

TABLE IV. RESULTS OBTAINED WITH PREHEATED RETORTS

Charge Number and Kind of Ore	Weight of Charge, lb.	Weight of Distilled Charge, lb.	Per Cent of Zinc in Charge	Per Cent of Zinc in Distilled Charge	Weight of Zinc in Charge, lb.	Kilowatt Intensity	Kw.-hr. Consumed	Kw.-hr. Consumed per Ton of Ore	Time of Distillation, Hr.	Temperature of Top of Retort at Beginning of Distillation, Deg. C.	Temperature at Top of Retort at End of Distillation, Deg. C.	Temperature of Base at Beginning of Distillation, b Deg. C.	Temperature of Base at End of Distillation, b Deg. C.	Weight of Zinc Dust Collected, lb.	Percentage of Recovery
24. Missouri silicate ore and dross briquets	3110	....	22.11	0.13	687.6	255	2170	2795	8.50	690	....	480	790		
25. Missouri silicate ore	3121	....	19.30	0.83	602.0	237	1300	1665	5.50	860	....	680	900		
26. Missouri silicate ore; some briquets made with old briquets as coke	3097	1759	16.23	Trace	502.0	234	1700	2190a	7.25	980	....	780	1415		
27. Missouri silicate ore; some briquets made with old briquets as coke	3022	1634	16.20	Trace	489.5	234	1170	1548a	5.00	1035	1460	560	970		
28. Franklinite briquets	3327	....	8.20	0.23	286.0	200	1185	1365	6.00	680	1125	230	400	236.0	82.5
29. Missouri silicate ore	3070	1627	16.45	0.15	505.0	225	1440	1811	6.40	970	1240	140	320	473.8	93.8
30. Missouri silicate ore	3168	1718	17.35	0.11	548.6	152	980	1237	6.50	1290	1310	520	660	523.2	95.1

a Overdistilled; unnecessarily high. b Temperature measured in brickwork of base.

small, since, in the nature of the process, the heat energy developed within the charge itself is at once consumed in useful work. The retorts can be heavily insulated. In Table V the low power consumption figures with a high degree distillation were obtained under condition of rapid work, and quick transfer of retorts. Continuous steady operation will also materially aid in condensation. All of the work was carried out on exceptionally low-grade ore, giving briquets containing from 16 to 20 per cent zinc. With higher grade ores, the briquets would contain from 25 to 30 per cent zinc, but it is not probable that the power consumption would increase proportionately, since the time is not necessarily increased and hence radiation losses are kept down.

TABLE V. POWER CONSUMPTION

Run Number	Kw.-hr. per Ton Ore	Per Cent Zinc Distilled *a* from Charge	Run Number	Kw.-hr. per Ton Ore	Per Cent Zinc Distilled *a* from Charge
1*b*	2540	100.0	16	2200	96.0
2	2270	100.0	17	1645	88.0
3	1540	54.0	18	2120	98.0
4*b*	3260	98.0	19*b*	3200	89.0
5	1645	98.0	20	1760	91.0
6	1720	85.0	21	1720	95.0
7*b*	2540	90.0	22	1920	97.0
8	2240	98.0	23	1760	95.0
9	2180	93.0	24*c*	2795	99.0
10	2420	96.0	25	1665	99.0
11	1760	73.0	26	2190	100.0
12	1600	70.5	27	1548	100.0
13	2700	100.0	28*d*	1365	99.0
14	2460	100.0	29	1811	99.0
15*b*	2620	100.0	30	1237	99.0

a Where less than all the zinc is distilled, the operation was purposely stopped to determine relation of extraction and power consumption.
b Initial charges.
c From hereon, operation with preheated retorts.
d Franklinite charge.

Zinc Dust Runs

Runs 28, 29, and 30 were made to produce zinc dust with furnace F. A condenser system consisting of two firebrick boxes, the first directly connecting with the vapor passage, and a 40-ft. train of 30-in. tile was connected with one base. To immediately cool the vapor at the exit of the vapor passage, an 8-in. iron pipe was passed through the first collecting box directly in front of the vapor passage; air was continually blown through this pipe. The zinc dust was of excellent quality throughout, free from oxide, 97 per cent passing a 200-mesh screen. The recoveries were very high, as will be noted from Table V.

Run 28 was made on franklinite ore, the briquets having the following composition: Ore, 100 parts; coke, 85 parts; and pitch, 28 parts. The briquets were in excellent condition after distillation, and it is probable that the coke and pitch proportions can be reduced. For the first large run on franklinite, it was considered undesirable to take any chance on composition.

General Characteristics of Process and Applications

The furnace and process presents the following characteristics:

1. It maintains the physical and metallurgical conditions of the present-day retort practice, in that it operates with a closed retort within the space of which is maintained a uniform temperature. This produces gas practically free from carbon dioxide, from which the zinc can be condensed as spelter without the formation of blue powder.

2. The energy for the distillation is generated within the charge itself, which fact, combined with proper heat insulation, will give the minimum power consumption possible.

3. It is a large unit furnace, the proposed 12-in. diameter, 72-in. high briquet, 19 per charge, will distill 8½ tons of roasted concentrate per 24 hr., counting on three distillations of 8 hr. each. The handling of material would all be done by crane, as in steel and copper plants. A general design has been worked out, in which the handling of material, the mixing of the briquet charge, the briquetting, the baking of briquets, the charging of retorts, and the discharge of the spent charge are done automatically and mechanically.

4. Probable costs have been calculated, which show a marked reduction over present costs. There will be no pottery and practically no consumption of fireclay. Labor costs will be low. Due to the completeness of distillation the recovery will be higher than in the present-day retort process. The cost of pitch in briquetting is not serious and with the great increase in by-product coke ovens the pitch supply will be plentiful. It has been suggested that the combination of a by-product plant and the electrical distilling furnace might work out well.

5. The process can be applied to any zinc ore, even to the so-called complex ores.

Platinum in 1919

The platinum market during the first quarter of 1919 was easier than in 1918, owing to the facts that the governmental restriction on the use of platinum had been removed and that the Government was disposing of its surplus stocks. The low price of $99 an oz. was reached late in March and was maintained about a month, but the price gradually stiffened until August, when the Government stocks were exhausted, and then abruptly rose to $110 an oz. Since the middle of August the price has continued to advance about $5 an oz. a month, the demand for the metal has been strong, and the supply has been short.

During the first nine months of 1919 about 40,400 oz. of platinum were imported, and if the importation at this rate continued during the rest of the year, and the normal domestic production of 7,000 to 10,000 oz. was maintained, about 54,800 oz. of new platinum should be available, aside from the stocks of platinum, about 65,000 oz., held at the beginning of 1919.

So far as known there has been little change in the domestic mining of platinum. The wide search made in 1918 for domestic sources of platinum has apparently yielded little results. Colombia may supply more crude platinum in 1920 than in the past, but its producing capacity is limited by the methods employed in washing the gravels from which the metal is obtained. Practically no supplies can be expected from Russia for several years. The osmiridium field of Tasmania appears to need only higher prices to stimulate larger production, but even with this stimulus it can probably produce not much more than 2,000 oz. a year.

According to James M. Hill of the United States Geological Survey, there seems to be little hope of any marked increase in the output of platinum in the United States or Canada over the small output heretofore made, and as the supplies are below normal and the demand is large it is reasonably certain that the price of platinum metals in this country during 1920 will be at least as high as it was during the last quarter of 1919, and possibly higher.

Foundry Test of Rotating Furnace

RECENT tests of operation of a 250-lb. Booth furnace* at Leitelt Bros. brass foundry, Chicago, in comparison with the performance of a gas-fired crucible installed in the same plant, furnished pertinent data on small electric furnace behavior. The electric equipment had been in operation for about two weeks when the test was initiated.

Detailed figures on the electric furnace for eleven days' run are given in Table I and on the gas-fired crucible for two heats in Table II. Table III shows comparison between the two equipments for an ordinary month's run, while in Table IV are assembled test data for four days out of the same month.

Notwithstanding somewhat adverse conditions under which this test was conducted, Table III shows a saving of over 36 per cent in melting cost in favor of the electric furnace. Furnace lining is estimated to cost in upkeep $1 per ton of metal, based on an estimated life of 400 heats. At the end of 425 heats, however, the lining was apparently as good as when first installed.

Conclusions From Test Data

Foundry records obtained while a furnace is hot are very misleading, because in a foundry such as the one being reported the average energy consumption will probably be more than 50 per cent in excess of the kilowatt-hours per ton consumed when melting regularly under the best conditions. Average operating results are therefore much better than records obtained under favorable test conditions. The electric brass furnace has proved itself to be a practicable piece of foundry equipment, irrespective of its energy consumption, but foundry men are apt to forget the over-all economies effected, and think only of the electric energy cost, if they find the kilowatt-hour consumption materially higher than was represented.

This furnace is not too small to melt red brass and gun metal with less than 290 kw.-hr. per ton (322 kw.-hr. per metric ton) and to melt yellow brass with about 240 kw.-hr. per ton (267 kw.-hr. per metric ton) when the furnace is hot and when it is being properly operated. It should be remembered, however, that furnaces are ordinarily used for one shift and allowed to cool down at night. This necessitates preheating each morning for an hour with about 50 kw. before the furnace is charged. Even this is not sufficient to heat up the furnace thoroughly, and it is not until afternoon that its point of highest efficiency is reached.

The inherent advantage of the electric furnace which overshadows all others is that it can melt metal with less loss than can the fuel-fired furnaces. As shown in Table III, a month's performance shows a shrinkage of 1.31 per cent in the one case as against 2.62 per cent in the other. Even a greater difference is noted when working on floor sweepings, turnings or light scrap.

In this particular foundry, concentrates from floor sweepings were sold for about 5c. per lb. before the electric furnace was installed, because it was not feasible to melt them in the crucibles. Now the electric furnace converts this material into ingots worth 15c. per pound.

Turnings and borings cost about 5c. per lb. less than ingots of the same analysis, and when charged into the electric furnace in large quantities, as can conveniently

*Described in CHEMICAL & METALLURGICAL ENGINEERING, vol. 21, p. 636.

TABLE I. SUMMARY OF DAILY RESULTS—11-DAY RUN

Day	No. of Heats	Time of Heat, Minutes	Material	Charge, Lb.	Poured, Lb.	Shrinkage Lb.	Shrinkage Per Cent	Kw.-Hr. Per Ton
1	6	59	Yellow brass	262	259	3	1.15	550
			Red brass, average	1442	1426.5	15.5	1.07	368
				1704	1685.5	18.5	1.09	394
2	7	53	Yellow Brass	710	700.5	9.5	1.34	338
			Red brass, average	963	955.5	7.5	0.78	648
				1673	1656	17	1.02	515
3	8	55	Yellow brass and manganese bronze	400	392.5	7.5	1.87	300
			Red brass and 85% copper bronze, average	1458.5	1440	18.5	1.27	428
				1858.5	1832.5	26	1.4	400
4	8	57	85% copper bronze	502	498	4	0.80	430
			Yellow brass	425	419	6	1.41	339
			Red brass, average	925	921.5	3.5	0.38	416
				1852	1838.5	13.5	0.73	402
5	5	65	Yellow brass	164	162.5	1.5	0.91	293
			Red brass and 85% copper bronze, average	1012.5	1003.5	9	0.89	544
				1176.5	1166	10.5	0.9	510
6	6	65	Red brass and 85% copper bronze	1367.75	1365	2.75	0.22	508
7	7	61	Red brass and 90% copper bronze	1723	1698	25	1.45	459
8	7	58	Yellow brass borings	83	74	9	10.83	867
			Red brass scrap, average	1697	1674.5	22.5	1.33	368
				1790	1748.5	31.5	1.80	391
9	7	51	Yellow borings	200	169	31	15.5	600
			Yellow brass scrap, average	1225	1221.75	3.25	27	488
				1425	1390.75	34.25	24	504
10	7	54	Yellow brass	125	107	18	14.4	384
			Red brass and bronze, average	1494	1490.5	3.5	0.23	380
				1619	1597.5	21.5	1.33	381
11	4	62	Red brass	977	972.5	4.5	0.44	442

SUMMARY

	Charged, Lb.	Poured, Lb.	Total Shrinkage Lb.	Total Shrinkage Per Cent
Red brass and 85% copper bronze	14,786.75	14,667.25	119.5	0.81
Yellow brass	1,961	1,933.25	27.5	1.40
Yellow brass borings	408	350	58	14.21

Analysis of the borings charged shows:

	Per Cent		Per Cent
Oil	8.28	Non-metallics charged	13.66
Non-metallic	5.38	Net metallic shrinkage	0.55
Metal	86.34		14.21

Power Consumption:
Average power consumption, 441-kw.-hr. per ton.

TABLE II. TESTS ON GAS FIRED CRUCIBLES

	Heat No. 1	Heat No. 2
Character of charge	Scrap	Scrap
Metal charged, lb.	165	250
Metal poured, lb.	156	245
Loss per cent.	5.75	2.04
Time, minutes	60	105
Gas used, cu. ft.	2040	3560
Gas, cu.ft. per ton	24,720	28,480
Average crucible consumption per ton, per cent.	44	44

TABLE III. COMPARATIVE COSTS

(Average cost of melting brass in electric furnace and gas-fired crucible during one month.)

	Electric cost per ton melted	Gas Cost per ton melted
Lb. of metal poured during month	35,215	18,210
Electric energy (480 kw.-hr.)	$13.64	.....
Gas (18,600 cu.ft.)	.....	$12.65
Labor	6.25	8.00
Lining	1.00	1.00
Crucibles	.....	7.00
Metal shrinkage, electric, 1.31 per cent at 18c. per lb.	4.71	.....
Metal shrinkage, gas, 2.62 per cent at 18c. per lb.	.....	9.42
Electrode consumption, 4 lb. at 27c. per lb.	1.08	.....
Gas for heating ladle 600 cu.ft. at 68c. per 1,000.	.41	.....
	$27.09	$38.07
Saving by use of cheaper scrap made possible by electric furnace	$2.88	.....
	$24.21	$38.07

TABLE IV. FOUR DAYS' TEST DATA, ELECTRIC MELTING

Day of test	1	2	3	4
Number of heats	6	8	4	1
Character of charge	Scrap	Ingot	Ingot	Gates
Weight charged, lb.	1698	2236	1012	275
Weight poured, lb.	1676	2229	1007	.....
Loss per cent.	1.3	.32	.47	.....
Energy per ton, kw.-hr.	354	412	474	436
Power factor, primary	.....	.....	.....	63
Power factor, secondary	71	70	70	71
Average weight per heat, lb.	283	280	252	275
Melting time per heat, min.	47	59.5	57	61
Copper charged, per cent.	80.58	76.59	85.30	81.81
Copper poured, per cent.	77.04	75.48	85.23	82.65
Lead charged, per cent.	6.97	10.18	4.92	4.67
Lead poured, per cent.	6.66	10.24	4.86	5.77
Tin charged, per cent.	4.66	8.04	1.83	2.25
Tin poured, per cent.	3.93	7.92	1.91	2.10
Zinc charged, per cent.	7.09	3.28	8.11	7.91
Zinc poured, per cent.	12.25*	2.93	9.48*	9.94*

*Zinc added in ladle.

be done, this one item will greatly increase the saving actually shown by the electric furnace in Table III.

Melting costs are really less vital than the better and more uniform quality of castings made from electrically melted metal. Up to the present time both gas and electric furnaces have been used in this foundry, and definite data are available in a number of castings made to meet navy specifications. Seventy-five per cent of the castings which were poured from the electric furnace passed this inspection, but only 10 per cent of those poured from crucibles came within the Government requirements.

Wood Distillation Study at Virginia Polytechnic Institute

An intensive study of wood distillation has been authorized by the Virginia Polytechnic Institute. Dr. J. B. McBryde, of the department of chemistry and chemical engineering of the Institute, who will be in charge of the work, points out that wood distillation already is being conducted on a commercial scale at several points where success has attended the efforts to recover the by-products from stumps and the waste material made during the manufacture of pine lumber. He believes that a careful study of the chemical problems involved will make possible a much more effective distillation and the recovery of many valuable byproducts which can be obtained from pine.

Recent Chemical and Metallurgical Patents

American Patents

Complete specifications of any of the United States patents may be obtained by remitting 10c. each to the Commissioner of Patents, Washington, D. C.

Concentrating Nitrous Gases.—There are several drawbacks in the processes used to concentrate nitrous gases. Thus when using alkaline solutions as absorbents, large quantities of liquid have to be evaporated. When absorbing in dry metal oxides, for instance in zinc oxide, these are usually of a so weakly basic nature that their absorbing effect is very small. A more efficient absorbent has been devised by BIRGER FJELD HALVORSEN of Christiania, Norway. A mixture of sodium hydroxide and ferric oxide or other metal oxide such as zinc oxide or aluminum oxide is used in the form of briquets. The reactions taking place when zinc oxide is used may be formulated as follows:

$$2NaOH + NO_2 + NO + ZnO = 2NaNO_2 + ZnO + H_2O$$

$$2NaOH + N_2O_4 + ZnO = NaNO_2 + NaNO_3 + ZnO + H_2O$$

The temperature of the gases not being too high, the zinc oxide remains unaltered.

Heat is then applied to cause the base and oxide to combine and we have

$$2NaNO_2 + ZnO = Zn(ONa)_2 + NO + NO_2$$

$$2NaNO_3 + ZnO = Zn(ONa)_2 + N_2O_5$$

Nitrous gases and sodium zincate are thus obtained. The gases are led off for use, and the residue, sodium zincate, is used over again at a lower temperature, acting as mixture of ZnO and Na_2O as follows:

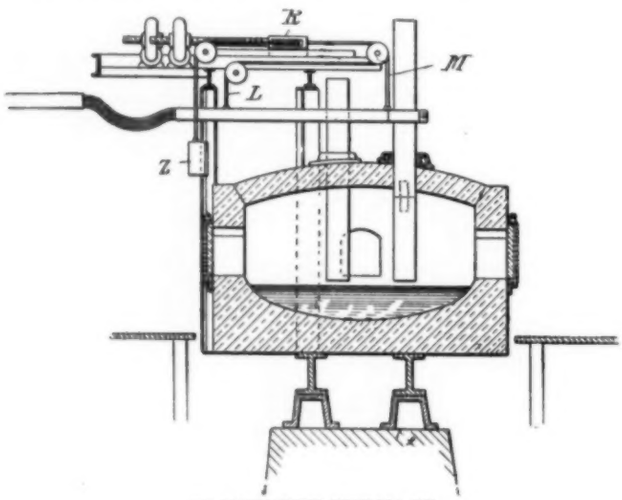
$$Zn(ONa)_2 + N_2O_4 = NaNO_2 + NaNO_3 + ZnO$$

(1,316,950; assigned to Norsk Hydro-Elektrisk Kvaelstofaktieselskab; Sept. 23, 1919.)

Process and Apparatus for Extracting Sulphur.—WILLIAM D. HUFF of LaFayette, La., has invented an apparatus for the economical recovery of sulphur from sulphur ore or other similar material containing native sulphur associated with gangue. The efficiency of the apparatus is dependent upon the melting of the sulphur in the absence of air and the conservation of a large portion of the heat imparted during the melting of the sulphur to the gangue and the parts of the apparatus which carry the sulphur-bearing material through the melting chamber. The sulphur ore is fed automatically to a series of buckets attached to rollers and formed into a continuous chain by means of links. This bucket conveyor dips beneath water contained in a tank, rises from the tank, passes through a melting chamber, and is again immersed in water in a second tank, passing over a sprocket wheel at the discharge end of the apparatus, where the gangue is dumped into cars for disposal. The two tanks containing water act as water seals for the melting chamber, thereby preventing the entrance of air to the chamber. The air is removed from the ore and the ore heated in the first tank. The heat of the gangue from which the sulphur has been removed in the melting chamber and the heat of the buckets, rollers and links are absorbed in the water in the second tank. The water is circulated through the tanks by a pump. Heat is provided to the melting chamber by means of a furnace. (1,317,625; Sept. 30, 1919; assigned one-half to James J. Connolly, of Roanoke, Va.)

Improved Sulphur Dyes From Waste Sulphite Liquor.—The fact that sulphur dyes can be prepared from concentrated waste sulphite liquor has been known for some time.[1] Such dyes may be improved, however, in the manner suggested by JACOB S. ROBESON of Pennington, N. J., by converting the calcium lignosulphonate into the corresponding salt of a heavy metal base. For example: 100 lb. of commercial 30 deg. Bé. waste sulphite liquor is mixed with 10 lb. of $FeSO_4$ dissolved in 40 lb. of H_2O. The precipitate of $CaSO_4$ is filtered off and the iron lignosulphonate precipitated from the filtrate by "salting out" with 30 lb. NaCl. After filtering and drying, the press cake is powdered, mixed with 42 lb. commercial sodium sulphide, 42 lb. sulphur and fused. When cold, the melt is pulverized. It is a black material which, dissolved in sodium sulphide solution, dyes cotton a brownish black, fast to sunlight and alkali. Sulphates of aluminum, copper, zinc, etc., may also be used, the dyes produced giving red brown, seal brown and gray brown respectively. (1,316,742; Sept. 23, 1919.)

Electrode Furnace.—WALDEMAR DYOSSEN of New York has developed an improved method of supporting the electrodes and electrode holders for furnaces of the Herould type, illustrated in the figure. The electrodes and holders are supported by cables *M* and *L* attached



ELECTRODE FURNACE

to common block *R*, which in turn is attached to threaded rod. This rod is movable by means of worm wheel and motor. An additional cable is looped through pulleys in blocks *R* and stationary pulleys located between the electrode holders. The free end of the cable is attached to counterweight *Z*. This arrangement makes possible the balancing of the weights of the electrodes and holders against each other, the weights *Z* being half the weight of one electrode and holder. This arrangement is advantageous in permitting the design of a furnace as free as practicable from heavy parts, the load on the motors being a minimum. (1,317,911; Oct. 7, 1919.)

Electrode.—SIGURD HEIER of Rjukan, Norway, increases the durability of rod electrodes in electric arc furnaces of the Schönherr type. This he accomplishes by modifying the shape of the furnace wall and also by providing a covering ring 5, Fig. 2. In Fig. 1 is illustrated the usual form of flame chamber, the flame taking a shape as shown by dotted lines 1. The rod electrode is shown at 2, the arrangement for water-cooling the electrode at 3. An insulated guide in the form of a ring is shown at 4. By modifying the shape of the furnace the arc flame takes the shape as shown

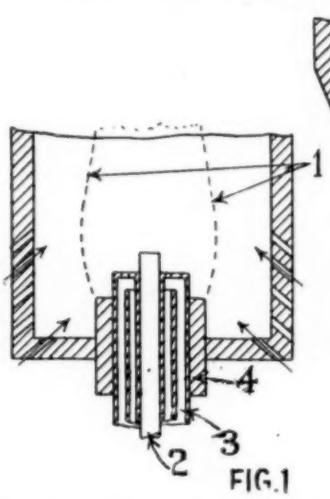


FIG. 1

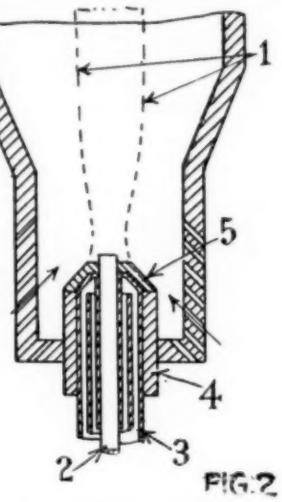


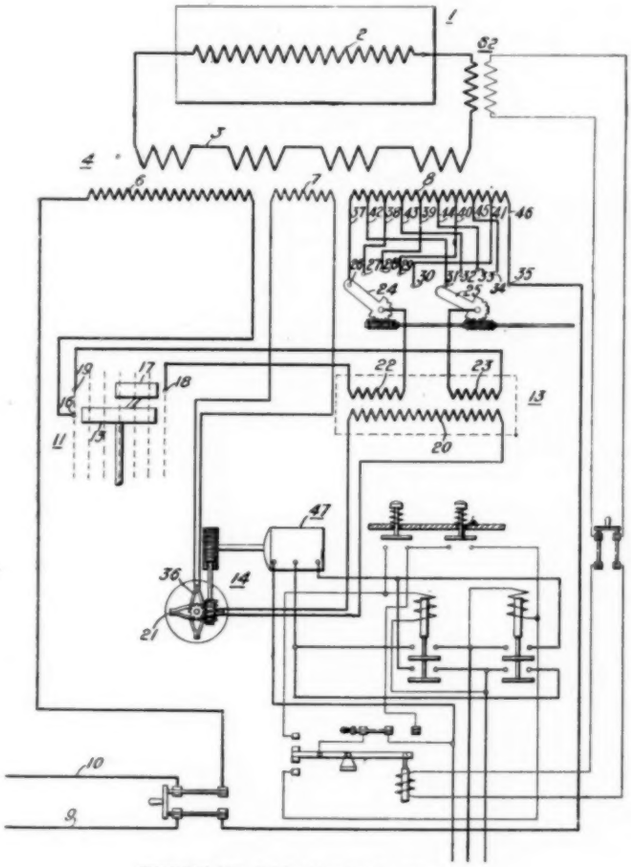
FIG. 2

by dotted lines 1 in Fig. 2. This together with the addition of the protective ring 5 increases the life of the electrode. (1,317,576; Sept. 30, 1919; assigned to Norsk Hydro-Elecktrist, Kvaelstofaktieselskab, of Christiania, Norway.

Furnace Regulator System.—EDWIN LEHR, of Pittsburgh, Pa., has devised a method of automatically or manually regulating the power input to electric resistor furnaces without causing abrupt changes in the furnace circuit. Where electric resistor furnaces have resistors with negative temperature coefficients it is desirable to avoid overheating of the furnace and resistor by reason of any abnormal flow of current. It is also desirable to maintain a uniform temperature within the furnace and therefore to regulate the power input. To be able to perform this regulation without causing excessive variations in the load upon the generator, furnace and other electrical equipment is decidedly advantageous. This method of accomplishing the regulation without causing either breaks or abrupt changes in the furnace circuit is best understood by referring to the sketch. The furnace 1 has a resistor 2 directly connected to the secondary 3 of the main transformer 4. The main transformer has two sets of primary windings 6 and 8, the portion 8 being provided with a series of taps 37 to 46, also an auxiliary winding 7. The primary windings of the main transformer are connected to the supply conductors 9 and 10 through a transfer switch 11 and through the switch arm 24 or 25. The transfer switch consists of a band 15 in contact with 16 at all times, and a segment 17 which extends slightly more than half around the circumference of the drum on which the band and segment are mounted. The segment 17 may make contact with either 18 or 19 or with both. The taps of section 8 of the main transformer are connected to contacts 26 to 35 and to the main circuit through switch arms 24 and 25. There is an auxiliary transformer 13 which has a primary winding 20 connected in series with the stationary coil 21 of the inductor regulator 14 and a secondary winding with two coils 22 and 23. The inductor regulator has

[1] Cf. Austrian patent 2336 (1889); *Paper Making*, vol. 36, p. 351 (1917).

in addition to the stationary coil 21 a movable coil 36 connected in series with the auxiliary winding 7 of the main transformer. The inductor regulator 14 and the tranfer switch 11 are rotated in unison by motor 47 through gearing which also controls the motion of switch arms 24 and 25. During one-half revolution of the transfer switch and the inductor regulator switch arm 25 makes contact with 31, then switch arm 24 breaks contact with 26, disconnecting that portion of the main transformer between taps 37 and 42. The switch arms are so proportioned that circuit through one arm is made before the circuit through the other arm is broken. The control of the voltage impressed upon the secondary of the main transformer is effected automatically by means of a control magnet and relay switches which control the motor 47. The changes in the electrical circuit and



FURNACE REGULATOR SYSTEM

the effect of these changes caused by a half revolution of the inductor regulator and transfer switch are these: The rotation of coil 36 of the inductor regulator impresses a voltage on the primary winding 20 of the auxiliary transformer 13, and, therefore, the energy input to the furnace. Just before the coil 36 has been rotated through one-quarter turn the impressed voltage has reached its maximum, which is one-half the voltage across two adjacent taps of the portion 8 of the main transformer. Switch arm 25 is now in contact with 31 and segment 17 of the transfer switch is in contact with 19. Accordingly the two secondary windings of the auxiliary transformer are connected in opposition and across the taps 37 and 42. The flow of current through coil 23 opposes the voltage of the supply current by an amount equal to one-half that across the taps 37 and 42. The further rotation of the transfer switch breaks the contact between segment 17 and 18, disconnecting coil 22. The current now flowing through coil 23 impresses a voltage in opposition to that of the main supply current and in amount equal to one-half that across the taps 37 and 42. The rotation of the inductor regulator through another quarter turn decreases the impressed voltage to zero and switch arm 24 has been disconnected from 26. This sequence of operations has therefore gradually increased the voltage impressed on the secondary of the main transformer by decreasing the number of turns in the primary winding and this change has been made gradually and without break in the circuit. (1,320,071; assigned to the Westinghouse Electric & Manufacturing Co., Oct. 28, 1919.)

Personal

Prof. WILDER D. BANCROFT has been delivering a series of scientific lectures of a popular nature on various phases of colloid chemistry. On Jan. 17 he addressed the Indiana Section of the American Chemical Society at Indianapolis, and he will speak on Jan. 22 and Jan. 29 before the Delaware Section, at Wilmington.

Prof. C. H. DESCH has resigned from the professorship of metallurgy at the Royal Technical College, Glasgow, to become professor of metallurgy at the University of Sheffield, England, in succession to Prof. C. O. Arnold.

C. H. FARNHAM is the chemist in charge of the laboratory recently equipped by the Spencer Heater Co., at Scranton, Pa.

F. A. J. FITZGERALD, of Niagara Falls, N. Y., has returned to the United States from a trip to Ireland.

JOHN CALDER HEBDEN has just returned from Europe, where he made extensive investigations of the chemical industry in France, England and Germany.

Dr. L. O. HOWARD, chief of the Bureau of Entomology of the United States Department of Agriculture, and for the past twenty-two years permanent secretary of the American Association for the Advancement of Science, has been elected president of that institution. Dr. EDWARD L. NICHOLS was elected general secretary in his place.

Major A. NAGELVOORT, who since receiving his discharge from the Chemical Warfare Service has been with the Matheson Alkali Works, Providence, R. I., is now with Arnold Hoffmann Co., Inc., selling agent for the Matheson Works.

ABRAHAM A. ORLINGER has been awarded the Chemists' Club Hoffman scholarship for 1919-20. Mr. Orlinger received his Bachelor of Science degree at the College of the City of New York, having specialized in chemistry, and is now pursuing the chemical engineering course at the Massachusetts Institute of Technology.

Dr. R. F. RUTTAN of McGill University is scheduled to deliver an address on "The Training of the Chemical Engineer" at the annual meeting of the Engineering Institute of Canada, Jan. 27-29.

LEWIS B. SKINNER, who recently severed his connection as general manager and vice-president of the Western Chemical Co., Denver, Col., will enter the consulting chemical and metallurgical field, with offices in Denver. He has recently been retained as consulting engineer for the Midwest Oil Co.

Prof. HAAKON STYRI has resigned from the faculty of the Carnegie Institute of Technology to assume the position of chief of the research laboratory of the S. K. F. Industries at Philadelphia, Pa.

Dr. LOUIS E. WISE has resigned from E. I. du Pont de Nemours & Co., with whom he was engaged in research at

their Jackson Laboratory at Wilmington, Del., to become professor of forest chemistry at the N. Y. State College of Forestry, Syracuse University, Syracuse, N. Y.

Obituary

RICHARD COCKBURN MACLAURIN, president of Massachusetts Institute of Technology since 1909, died on Jan. 15 of pneumonia at his home in Cambridge. During Dr. MacLaurin's eleven years as president, the Institute has received large endowments and increased its educational facilities enormously. Being primarily a mathematician and an investigator of the phenomena of light, Dr. MacLaurin became a close friend of George Eastman, who has just been identified as the mysterious Mr. S-MIT-H and donor of $11,000,000 to Tech.

Dr. MacLaurin was born at Lindean, Scotland, June 5, 1870. In 1896 and 1897, he received the Bachelor of Arts and Master of Arts degrees from St. John's College, University of Cambridge. For the next ten years he was professor of mathematics and during the two last years was dean of the law school of the University of New Zealand. In 1907 he was professor of mathematical physics at Columbia University and had just been appointed head of the physics department, when he resigned to become president of Technology.

Dr. MacLaurin's work in advancing the Institute to its present dominant position will place his name foremost among the educators of the present era.

Current Market Reports

The Non-Ferrous Metal Market

New York, Jan. 19—Copper is quoted at the same figure as last week. Nickel and lead advanced 1c. and ¾c., respectively; while tin declined 1¾c.

	Cents per Lb.
Copper, electrolytic	19.50
Aluminum, 98 to 99 per cent	31½ @ 32½
Antimony, wholesale lots	10.12½
Nickel, ordinary	43.00
Nickel, electrolytic	46.00
Tin, Straits, spot	62.75
Lead, New York, spot	8.75
Lead, E. St. Louis, spot	8.37½
Zinc, spot, New York	9.55
Zinc, spot, E. St. Louis	9.22½
Silver (Dollars per oz.)	1.30¼

FINISHED METAL PRODUCTS

	Warehouse Price Cents per Lb.
Copper sheets, hot rolled	29.50
Copper sheets, cold rolled (over 14 oz.)	31.50
Copper bottoms	38.00
Copper rods	27.50
High brass wire and sheets	25.25
High brass rods	23.75
Low brass wire and sheets	27.25
Low brass rods	28.00
Brazed brass tubing	37.00
Brazed bronze tubing	41.75
Seamless copper tubing	33.50
Seamless bronze tubing	34.50
Seamless brass tubing	30.50

SCRAP METALS

	Cents Per Lb.
Aluminum, cast scrap	23½ @ 24½
Aluminum, sheet scrap	22½ @ 23½
Aluminum clippings	25½ @ 27
Copper, heavy machinery comp.	14½ @ 14¾
Copper, heavy and wire	13¾ @ 14
Copper, light and bottoms	12½ @ 12¾
Copper, heavy cut and crucible	15½ @ 16
Brass, heavy	7½ @ 8½
Brass, casting	10½ @ 10¾
Brass, light	5½ @ 6½
No. 1 clean brass turnings	8½ @ 8¾
No. 1 comp. turnings	12 @ 12½
Lead, tea	4½ @ 5
Lead, heavy	6¾ @ 6½
Zinc, scrap	4½ @ 4¾

RARER METALS

Cadmium	lb.	$1.50 @ 2.50
Cobalt	lb.	1.90
Platinum	oz.	150.00
Iridium	oz.	250.00
Palladium	oz.	150.00
Mercury	75 lb.	93.00

The Iron and Steel Market

Pittsburgh, January 16, 1920.

The famine in steel products is unabated, as is evidenced by as high prices as formerly being paid for prompt shipment of certain products, particularly sheets, merchant bars, wire nails and plates, and in a few instances still higher prices. Also it is observed that in occasional instances, particularly in the case of sheets, mills that were obtaining large premiums for first quarter deliveries are now able to effect some future sales at the same prices.

PRODUCTION INCREASING

Production of steel continues to increase, though at no rapid rate, and may now be estimated at a trifle over 80 per cent of capacity. Labor shortage is much less a limiting factor than formerly, there being now relatively little labor shortage, in point of numbers, but there is still much to make up in point of efficiency, so many men being new to their employment, either from having shifted from one mill to another during the strike or from being entirely new to the steel industry. As the difficulty is almost wholly with common labor, it is to be expected that the teaching necessary can be completed with a month or two. The wire mills have been exceptionally short of labor, but have had a noticeable accretion of men in the past week.

The coke supply continues to be an important limiting factor in pig iron and therefore also in steel production. The shortage, as it appears in the market, is substantially as great as a few weeks ago, but the shortage has continued not because of production being curtailed, but because the consumptive demand has increased. The by-product ovens are doing distinctly better week by week, while the Connellsville region is increasing slightly, by a very few per cent in each of the past two or three weeks. The limiting factor in coke production is car supplies, at the beehive ovens of the Connellsville region and at the coal mines attempting to serve the byproduct ovens.

SALES AT VARIOUS PRICES

The occasional or chance buyer can secure steel, in the case of most of the finished products, only at prices much above the March 21 or "stabilized" price schedule, while consumers with regular mill connections frequently pay similar prices on extra tonnages, beyond what their regular sources of supply will allot them. In one sense these advanced prices represent "the market," though even from that viewpoint the market is not a quotable one, seeing that the price varies according to the buyer, the tonnage and the delivery. The great bulk of the business transacted, however, is at the March 21 prices, and in that sense the stabilized schedule is still "the market." Of sales made in December probably more than 75 per cent were made at the March 21 schedule. There are some predictions that the market will be a runaway, getting out of control of the Steel Corporation and other interests that desire to hold it to the March 21 schedule, and there are even claims made that the control has already been lost. Such statements and predictions appear to be premature. When time has been allowed for increased production to show what impress it can make upon the situation, a better basis for prediction will be afforded.

Sales in December may be analyzed with some closeness on account of the Steel Corporation's operations being known. The corporation's unfilled obligations at the end of December amounted to 8,265,366 tons, showing an increase during December of 1,137,036 tons. Shipments were about 950,000 tons, so that bookings were in the neighborhood of 2,100,000 tons. No sales were made by the corporation at above the March 21 schedule, but a portion of the business booked and reported as unfilled obligations, probably a relatively small proportion, did not have a price affixed, delivery being so extended that the price matter was left open. While the Steel Corporation by last accounts represents about 44 per cent of the steel industry (excluding the iron mills from the reckoning), the independents sold in December a much smaller tonnage. Those that have refrained from advancing above the March 21 prices were very reserved in selling, while in the case of those who were asking higher prices there was the double restriction that they were not willing to sell large tonnages and the

buyers were unwilling to contract for large tonnages. Thus it is safe to guess that three-fourths, and probably considerably more, of the steel business done in December was at not over the March 21 schedule.

Railroad Buying

While in practically all quarters the steel market situation is painted as being a very strong one, it can be observed that some of the colors used are not necessarily permanent. In particular, there is the assumption that the railroads will be large buyers after March 1, when the lines are to be returned to their owners. This view is hardly entitled to be called even a theoretical conclusion. Steel mills will not be operated upon what the public or even the railroad interests think they ought to have, but upon orders for steel the railroads are able and willing to buy and pay for. The president of the Pennsylvania Railroad has expressed himself that it is a waste of energy to consider at this juncture a program of extensive expansion of railroads during the next few years, explaining that the three things to be considered first are: Funding of the debts due from railroads to the Government for improvements made during the control period whereby the roads are handed back to the owners in better condition than when received, providing for obligations soon to mature, and providing for capital expenditures of the ordinary size.

As to large purchases of rails being about to exercise an influence upon the steel market situation, it ought to be observed that reservations have already been made, and are therefore a part of the reckoning of the steel mills, and that these reservations, with orders previously placed and stocks of rails now held by the roads, are sufficient to take care of a year's normal replacement plus any deficit that may have occurred in the past two years. The figures available are probably not consulted by those who make predictions as to rail purchases. Replacements during the three years taken as the test period to fix the rental to be paid by the Government should furnish a criterion, and averaged 1,328,316 tons a year. Replacements in 1918 were 1,111,638 tons and in 1919 about 1,350,000 tons, the two years thus showing a total deficit of 200,000 tons as compared with the experience in the test period. Stocks Jan. 1, 1920, were 375,000 tons and rails on order about 200,000 tons, while reservations already made amount to nearly if not quite a million tons.

The Chemical Market

New York, January 16, 1920.

Large manufacturers have avoided speculation and are serving their customers on the old basis wherever possible. It has become a habit of many engaged in the trade to have large stocks on hand when a shortage threatens and then dump it out at a greatly increased price. The result is an uncertainty in supply and price, as the mere rumored report of a scarcity has sent prices bouncing skyward. A fair example of this is the recent jump in *bichromate of soda*, which had a sensational rise until some hitherto unknown stocks were discovered and turned loose. Prices continued upward, then came the break and descending action back to normal. It is not often that business men of ripe experience are bitten twice by the same insect and it is the consensus of opinion that this latest rise is due to a real scarcity.

Bicarbonate of soda is again tending upward, due to a real scarcity, being quoted at 20@21c. per lb. Spot stocks on this item are scarce and it is rumored that under the present demand new price levels will be reached. *Wood alcohol* is unobtainable, the quotation remaining nominal at \$4.80@\$4.95 per gal. for carlots, \$5.50@\$7 per gal. for less than carlots. *Denatured, 188 proof*, is quoted at 76@78c. per gal., while 190 proof is quoted at 71@73c. It is rumored that the Government has withdrawn formula 1 for the manufacture of denatured alcohol, substituting a new one which will use considerably less wood alcohol and substitute pyradine, thus lowering the price on denatured and lessening the demand on wood alcohol. Manufacturers of wood alcohol are confronted with the difficulty of obtaining raw materials, and the orders placed by Japan last June and July for January delivery are now being filled, which accounts for the extreme shortage of wood alcohol.

Oxalic crystals remain firm under an increased demand, and at present there is some difficulty in obtaining this item on spot. *Caustic soda* has been the center of interest, the quotation remaining \$4.30@\$4.50, but some sales have been reported as high as \$4.65 per cwt. As all of the producers are sold up on this, it is practically impossible to obtain this item on early delivery. A strong market on *sal ammoniac* is the record for the past week, being quoted at 12¾@14c. per lb., with very little material available at this price. The coal supply is responsible for the strengthening in the ammonia grades, and this shortness will continue until there is a settlement in the coal industry. Formaldehyde has probably been the strongest feature of the market, speculation increasing and the actual supply diminishing. A larger production of alcohol is the only relief in sight from this present stringency. *Potassium carbonate* is now quoted at 26@27c. per lb., against 25c. of last week.

Coal-Tar Products. The shortage of raw materials is interfering with the manufacturers of these materials, some of the firms having withdrawn their names as producers of certain items in order to keep them for their own use in producing the finished product. The prices asked for *alpha naphthylamine* range from 35c. to 45c., while *crushed naphthaline* used as a base for beta naphthol is sold up to July by some producers. Among the short items of the coal-tar products, *benzol*, pure water white, remains nominally quoted at 27@31c. per gal. The shortage on this item is an after-effect of the recent coal strike, but it is expected that there will be some material available around March 1.

Interest in the *waxes* has quickened during the past week, but prices still stand firm. There has been an increase of ¼c. per lb. on the two highest grades of *paraffine*, quotations now being on 133 to 135 m.c., 12c. and on 135 to 137 m.c., 13c. per lb.

In sympathy with the Savannah market, local dealers have advanced the price on *turpentine* to \$1.97, with some sales recorded as high at \$2.05. This jump from \$1.60 of a few weeks ago has not been caused by any shortage in supply, but principally because of speculation in the London markets, where it was reported this item was short. The tremendous building campaign planned in England has caused this speculation. The London market at present is quoted around \$2.10.

Vegetable Oils. The *linseed oil* market is very dull, business being at a minimum. Consumers are well covered for some time to come. The quotation of \$1.77 per gal. still holds. The arrival of flaxseed from Buenos Aires continues heavy, several ships having arrived with reported cargoes of 53,000, 8,000 and 7,000 bags on board. The entrance of soap manufacturers as buyers in the vegetable oil field has had a tendency to strengthen all items on the list, noticeably *palm lagos*, which has increased to 17@18c. per lb., and peanut oil, which also jumped a cent to 24½c. per lb. It is the opinion of some that the price of 20@20¾c. per lb. for *cocoanut oil*, Ceylon grade, is not sufficient to meet the increased expenses of the crusher and this item will have a rise shortly.

Ores and Semi-Finished Products

Ferro-alloy market. General firmness in price and stronger demand in some lines marks the past week. Import and export inquiries have been heavy on ferromanganese, quoted at \$140@\$150 gross ton. Large demands and small stocks have occasioned this gradual rise from \$130 of a few weeks past. *Spiegeleisen* continues under heavy demand because of its manganese contents of from 19 to 20 per cent, and is now quoted at \$40@\$50 per ton.

Among the *ores* and *semi-finished* products, *manganese* is probably the most active, inquiry being very heavy. The present quotation remains at 50@75c. per unit. *Coke* production still remains from 30 to 60 days behind schedule, and with only 30 to 35 per cent of the normal number of cars in operation, no relief is in sight. *Barytes*, white floated domestic, remains \$35@\$40 per ton in quotation for January contract, but it is expected there will be a rise in price for February quotations.

General Chemicals

CURRENT WHOLESALE PRICES IN NEW YORK MARKET

		Carlots	Less Carlots
Acetic anhydride	lb.	–	$0.60 – $0.65
Acetone	lb.	$0.16 – $0.20	.21 –
Acid, acetic, 28 per cent.	cwt.	2.50 – 3.00	3.00 – 3.25
Acetic, 56 per cent.	cwt.	5.00 – 5.50	6.00 – 6.50
Acetic, glacial, 99½ per cent, carboys	cwt.	12.00 – 12.50	13.50 – 15.50
Boric, crystals	lb.	.14½ – .15½	.15½ – .16½
Boric, powder	lb.	.14½ – .15	.15 – .16
Hydrochloric (muriatic), tech. 20 deg.	cwt.	2.25 –	– 2.50
Hydrofluoric, 52 deg.	lb.	.12 –	.14 –
Lactic, 44 per cent tech.	lb.	.11 – .11½	.12 – .16
Lactic, 22 per cent tech.	lb.	.05 – .06	.05½ – .07
Molybdic, C. P.	lb.	–	4.00 – 4.25
Nitric, 40 deg.	lb.	.06 – .06½	.07 – .08½
Nitric, 42 deg.	lb.	.06½ – .07	.08 –
Oxalic, crystals	lb.	.31 – .32	.32 – .35
Phosphoric, Ortho, 50 per cent solution	lb.	.09 –	.10 – .14
Picric	lb.	.30 – .35	.40 – .50
Pyrogallic, resublimed	lb.	2.20 – 2.40	2.30 – 2.60
Sulphuric, 60 deg., tank cars	ton	17.50 – 22.00	–
Sulphuric, 60 deg., drums	ton	– 30.00	–
Sulphuric, 60 deg., carboys	ton	–	–
Sulphuric, 66 deg., tank cars	ton	22.00 – 25.00	–
Sulphuric, 66 deg., drums	ton	–	–
Sulphuric, 66 deg., carboys	ton	–	–
Sulphuric, fuming, 20 per cent (oleum) tank cars	ton	25.00 –	30.00 –
Sulphuric, fuming, 20 per cent (oleum) drums	ton	28.00 –	32.00 –
Sulphuric, fuming, 20 per cent (oleum) carboys	ton	35.00 –	40.00 –
Tannic, U. S. P.	lb.	–	1.35 – 1.45
Tannic (tech.)	lb.	–	.42 – .55
Tartaric, crystals	lb.	–	.69 – .74
Tungstic, per lb. of WO	lb.	–	1.20 – 1.40
*Alcohol, Ethyl	gal.	4.80 – 5.50	6.00 – 7.00
*Alcohol, Methyl	gal.	1.50 –	1.52 – 1.57
*Alcohol, denatured, 188 proof	gal.	–	.76 – .78
*Alcohol, denatured, 190 proof	gal.	–	.71 – .73
Alum, ammonia lump	lb.	.04½ – .05	.04½ – .04¾
Alum, potash lump	lb.	.08 – .08¾	.09 – .09½
Alum, chrome lump	lb.	.15 – .16	.18 – .20
Aluminum sulphate, commercial	lb.	.01¾ – .02	.02½ – .02¾
Aluminum sulphate, iron free	lb.	.02¾ – .03	.03½ – .03½
Aqua ammonia, 26 deg., drums (750 lb.)	lb.	.08¾ – .10¾	.11 – .12
Ammonia, anhydrous, cylinders (100-150 lb.)	lb.	–	.30 – .33
Ammonium carbonate, powder	lb.	.13 – .16½	.17 – .17½
Ammonium chloride, granular (white sal ammoniac)	lb.	.12½ – .14	.13½ – .17½
Ammonium chloride, granular (gray sal ammoniac)	lb.	.12 – .12½	.13 – .13½
Ammonium nitrate	lb.	.22 –	.06 –
Ammonium sulphate	lb.	.05 –	3.65 – 3.75
Amylacetate	gal.	–	.10½ – .11
Arsenic, oxide, lumps (white arsenic)	lb.	–	–
Arsenic, sulphide, powdered (red arsenic)	lb.	.23 – .24	.24 –
Barium chloride	ton	80.00 – 85.00	100.00 – 110.00
Barium dioxide (peroxide)	lb.	.22 –	.11 – .12
Barium nitrate	lb.	.09½ – .10½	.11 – .12
Barium sulphate (precip.) (blanc fixe)	lb.	.03 – .03½	.03½ – .04
Bleaching powder (see calcium hypochlorite)		–	–
Blue vitriol (see copper sulphate)		–	–
Borax (see sodium borate)		–	–
Brimstone (see sulphur, roll)		–	–
Bromine	lb.	.90 – .95	–
Calcium acetate	cwt.	2.00 – 2.05	2.10 –
Calcium carbide	lb.	–	.04¾ – .05
Calcium chloride, fused, lump	ton	20.00 – 25.00	30.00 – 40.00
Calcium chloride, granulated	lb.	.01½ – .01¾	.02 – .02½
Calcium hypochlorite (bleaching powder)	cwt.	–	2.50 – 3.75
Calcium peroxide	lb.	–	1.50 – 1.70
Calcium phosphate, monobasic	lb.	–	.75 – .80
Calcium sulphate, pure	lb.	–	.25 – .30
Carbon bisulphide	lb.	.05½ –	.06 – .09
Carbon tetrachloride, drums	lb.	.10½ – .11	.12 – .15½
Carbonyl chloride (phosgene)	lb.	–	.75 –
Caustic potash (see potassium hydroxide)		–	–
Caustic soda (see sodium hydroxide)		–	–
Chlorine, gas, liquid-cylinders (100 lb.)	lb.	.05 – .05½	.08 –
Cobalt oxide	lb.	–	1.50 – 1.55
Copperas (see iron sulphate)		–	–
Copper carbonate, green precipitate	lb.	–	.28 – .31
Copper cyanide	lb.	–	.65 – .70
Copper sulphate, crystals	lb.	.07½ – .08¾	.09 – .09½
Cream of tartar (see potassium bitartrate)		–	–
Epsom salt (see magnesium sulphate)		–	2.30 – 2.50
Formaldehyde, 40 per cent	lb.	–	.51 – .52
Glauber's salt (see sodium sulphate)		–	–
Glycerine	lb.	–	.24½ – .26
Iodine, resublimed	lb.	–	4.10 – 4.30
Iron oxide, red	lb.	–	.03 – .20
Iron sulphate (copperas)	cwt.	1.00 –	1.20 – 1.75
Lead acetate, normal	lb.	–	.20 – .23
Lead arsenate (paste)	lb.	–	.13 – .17
Lead nitrate, crystals	lb.	–	.30 – .35
Litharge	lb.	–	.09½ – .10¼
Lithium carbonate	lb.	–	1.50 –
Magnesium carbonate, technical	lb.	–	.13 – .14½
Magnesium sulphate, U. S. P.	100 lb.	2.15 – 2.63	2.75 – 3.00
Magnesium sulphate, commercial	100 lb.	1.75 –	2.00 – 2.50
Nickel salt, double	lb.	.14 –	.15 –
Nickel salt, single	lb.	.12 –	.15 – .16
Phosgene (see carbonyl chloride)		–	–
Phosphorus, red	lb.	–	.75 – .90
Phosphorus, yellow	lb.	–	.35 – .37
Potassium bichromate	lb.	.28 – .33	.34 – .35
Potassium bitartrate (cream of Tartar)	lb.	–	.56 – .60
Potassium bromide, granular	lb.	–	.50 – .65
Potassium carbonate, U. S. P.	lb.	.60 –	.65 – .70
Potassium carbonate, crude	lb.	.26 – .27	.28 – .30
Potassium chlorate, crystals	lb.	.16 – .20	.21 –
Potassium cyanide, 98-99 per cent.	lb.	nominal	
Potassium hydroxide (caustic potash)	lb.	.23 – .32	.35 – .42
Potassium iodide	lb.	–	3.35 – 3.60
Potassium nitrate	lb.	.19 –	.21 –
Potassium permanganate	lb.	–	.65 – .95
Potassium prussiate, red	lb.	–	1.10 – 1.20
Potassium prussiate, yellow	lb.	–	Less Carlots $0.40 – $0.70
Potassium sulphate	ton	$225.00 –	–
Rochelle salt (see sodium potas. tartrate)		–	–
Sal ammoniac (see ammonium chloride)		–	–
Sal soda (see sodium carbonate)		–	–
Salt cake (sodium sulphate)	ton	18.00 – 21.00	–
Silver cyanide	oz.	–	1.25 –
Silver nitrate	oz.	–	.81½ – .82½
Soda ash, light	100 lb.	2.05 –	2.25 –
Soda ash, dense	100 lb.	2.25 – 2.35	2.50 – 2.75
Sodium acetate	lb.	.06½ – .07	.07 – .08
Sodium bicarbonate	100 lb.	2.40 –	2.75 – 3.00
Sodium bichromate	lb.	.20 – .21	.22 – .25
Sodium bisulphate (nitre cake)	ton	3.00 – 8.00	10.00 –
Sodium bisulphite	cwt.	1.80 – 1.90	2.00 – 2.10
Sodium borate (borax)	lb.	– .08	.08½ – .09
Sodium carbonate (sal soda)	100 lb.	1.40 – 1.55	1.50 – 1.75
Sodium chlorate	lb.	.10 –	.12 – .14
Sodium cyanide, 96-98 per cent.	lb.	.30 –	.31 – .34
Sodium fluoride	lb.	.14 –	.15 – .16
Sodium hydroxide (caustic soda)	100 lb.	–	4.30 – 4.50
Sodium hyposulphite	lb.	–	.03½ – .04
Sodium molybdate	lb.	2.50 –	3.25 –
Sodium nitrate	100 lb.	3.00 – 3.25	3.75 – 4.00
Sodium nitrite	lb.	.15 – .17	– .18
Sodium peroxide, powdered	lb.	–	.30 – .32
Sodium phosphate, dibasic	lb.	.03½ – .04½	.04½ – .05
Sodium potassium tartrate (Rochelle salt)	lb.	–	.43 – .45½
Sodium prussiate, yellow	lb.	.23 – .39	.24 – .40
Sodium silicate, solution (40 deg.)	lb.	.01½ – .02	.02 – .02½
Sodium silicate, solution (60 deg.)	lb.	.02½ – .03	.03½ – .04½
Sodium sulphate, crystals (Glauber's salts)	cwt.	1.30 – 1.50	1.60 – 2.00
Sodium sulphide, crystal, 60-62 per cent. (conc.)	lb.	–	.05 – .06
Sodium sulphite, crystals	lb.	.03½ –	.04 – .06
Strontium nitrate, crystals	lb.	.25 –	.28 –
Sulphur chloride	lb.	.05½ –	.06 –
Sulphur, crude	ton	22.00 –	–
Sulphur dioxide, liquid, cylinders	lb.	.09 –	.10 – .12
Sulphur (sublimed), flour	100 lb.	3.35 –	3.40 – 3.65
Sulphur, roll (brimstone)	100 lb.	3.20 –	3.30 – 3.40
Tin bichloride (stannous)	lb.	.42½ –	.46 – .50
Tin oxide	lb.	.43 –	.60 –
Zinc carbonate, precipitate	lb.	–	.20 –
Zinc chloride, gran.	lb.	.12½ –	.13½ – .15
Zinc cyanide	lb.	.49 –	.50 –
Zinc dust	lb.	.09 – .11	.11 – .14
Zinc oxide, dry American	lb.	–	.09½ – .12
Zinc sulphate	lb.	.03½ – .03¾	.04 – .04¼

*Nominal quotations.

Coal-Tar Products

NOTE—The following prices are for original packages in large quantities:

Alpha naphthol, crude	lb.	$1.00 —	$1.10
Alpha naphthol, refined	lb.	1.40 —	1.50
Alpha naphthylamine	lb.	.34 —	.37
Aniline oil, drums extra	lb.	.34 —	.37
Aniline salts	lb.	.43 —	.48
Anthracine, 80% in drums (100 lb.)	lb.	.75 —	1.00
Benzaldehyde (f.f.c.)	lb.	1.75 —	–
Benzidine, base	lb.	1.10 —	–
Benzidine, sulphate	lb.	.90 —	1.00
Benzoic acid, U.S.P.	lb.	.90 —	1.10
Benzoate of soda, U.S.P.	lb.	.80 —	1.00
Benzol, pure, water-white, in drums (100 lb.)	gal.	.27 —	.31
Benzol, 90%, in drums (100 lb.)	gal.	.25 —	.29
Benzyl chloride, 95-97%, refined	lb.	.35 —	.40
Benzyl chloride, tech.	lb.	.25 —	.35
Beta naphthol benzoate	lb.	.50 —	.52
Beta naphthol, sublimed	lb.	.75 —	.80
Beta naphthol, tech.	lb.	.45 —	.55
Beta naphthylamine, sublimed	lb.	2.25 —	2.35
Cresol, U.S.P., in drums (100 lb.)	lb.	.18 —	–
Ortho-cresol, in drums (100 lb.)	lb.	.23 —	.25
Cresylic acid, 97-99%, straw color, in drums	gal.	.75 —	.80
Cresylic acid, 95-97%, dark, in drums	gal.	.72 —	.75
Cresylic acid, 50%, first quality, drums	gal.	.60 —	–
Dichlorbenzol	lb.	.07 —	.10
Diethylaniline	lb.	1.40 —	2.25
Dimethylaniline	lb.	.90 —	1.00
Dinitrobenzol	lb.	.26 —	.37
Dinitroclorbenzol	lb.	.25 —	.30
Dinitronaphthaline	lb.	.45 —	.55
Dinitrophenol	lb.	.32 —	.36
Dinitrotoluol	lb.	.38 —	.45
Dip oil, 25%, tar acids, car lots, in drums	gal.	.38 —	.40
Diphenylamine	lb.	.58 —	.75
H-acid	lb.	1.60 —	1.75
Metaphenylenediamine	lb.	1.15 —	1.80
Monochlorbenzol	lb.	.12 —	.15
Monoethylaniline	lb.	1.50 —	1.75
Naphthaline crushed, in bbls. (250 lb.)	lb.	.06 —	.08
Naphthaline, flake	lb.	.07 —	.08
Naphthaline, balls	lb.	.08½ —	.10
Naphthionic acid, crude	lb.	.75 —	1.25
Nitrobenzol	lb.	.14 —	.19
Nitro-naphthaline	lb.	.30 —	.35
Nitro-toluol	lb.	.27 —	.30
Ortho-amidophenol	lb.	3.00 —	4.25
Ortho-dichlor-benzol	lb.	.15 —	.20
Ortho-nitro-phenol	lb.	.90 —	1.25
Ortho-nitro-toluol	lb.	.25 —	.40
Ortho-toluidine	lb.	.25 —	.45
Para-amidophenol, base	lb.	2.50 —	3.50
Para-amidophenol, HCl	lb.	2.50 —	3.25
Para-dichlor-benzol	lb.	.15 —	.18
Paranitraniline	lb.	1.00 —	1.20
Para-nitro-toluol	lb.	1.35 —	1.50
Paraphenylenediamine	lb.	2.50 —	4.00
Paratoluidine	lb.	2.00 —	2.50
Phthalic anhydride	lb.	.70 —	1.00
Phenol, U.S.P., drums (dest.), (240 lb.)	lb.	.12½ —	.19
Pyridin	gal.	2.00 —	2.50
Resorcin, technical	lb.	3.75 —	4.50
Resorcin, pure	lb.	6.50 —	6.75
Salicylic acid, tech., in bbls. (110 lb.)	lb.	.45 —	.60
Salicylic acid, U.S.P.	lb.	.45 —	.50
Salol	lb.	.90 —	.95
Solvent naphtha, water-white, in drums, 100 gal.	gal.	.22 —	.27
Solvent naphtha, crude, heavy, in drums, 100 gal.	gal.	.19 —	.24
Sulphanilic acid, crude	lb.	.25 —	.30

Toluidine	lb.	$1.70 —	$2.50
Toluidine, mixed	lb.	.45 —	.55
Toluol, in tank cars	gal.	.28 —	....
Toluol, in drums	gal.	.29 —	.32
Xylidine, drums, 100 gal.	lb.	.44 —	.50
Xylol, pure, in drums	gal.	.37 —	.45
Xylol, pure, in tank cars	gal.	.35 —	....
Xylol, commercial, in drums, 100 gal.	gal.	.37 —	.45
Xylol, commercial, in tank cars	gal.	.23 —	.27

Waxes

Prices based on original packages in large quantities.

Beeswax, natural crude, yellow	lb.	$0.42 —	$0.45
Beeswax, refined, yellow	lb.	.47 —	.48
Beeswax, white, pure	lb.	.63 —	.68
Carnauba, No. 1	lb.	.80 —	.88
Carnauba, No. 2, regular	lb.	.65 —	.78
Carnauba, No. 3, North Country	lb.	.43 —	.48
Japan	lb.	.18½ —	.20
Paraffine waxes, crude match wax(white) 105-110 m.p.	lb.	.06 —	.07
Paraffine waxes, crude, scale 124-126 m.p.	lb.	.... —	.06½
Paraffine waxes, refined, 118-120 m.p.	lb.	.... —	.09½
Paraffine waxes, refined, 128-130 m.p.	lb.	.09½ —	.10½
Paraffine waxes, refined, 133-135 m.p.	lb.	.... —	.12
Paraffine waxes, refined, 135-137 m.p.	lb.	.... —	.13
Stearic acid, single pressed	lb.	.23 —	.26
Stearic acid, double pressed	lb.	.28 —	.29
Stearic acid, triple pressed	lb.	.32 —	.33

NOTE—Quotations on paraffine waxes are nominal.

Flotation Oils

All prices are f.o.b. New York, unless otherwise stated, and are based on carload lots. The oils in 50-gal. bbls., gross weight, 500 lb.

Pine oil, steam dist., sp.gr., 0.930-0.940	gal.	$1.30
Pine oil, pure, dest. dist.	gal.	....
Pine tar oil, ref., sp.gr. 1.025-1.035	gal.	.40
Pine tar oil, crude, sp.gr. 1.025-1.035 tank cars f.o.b. Jacksonville, Fla.	gal.	.35
Pine tar oil, double ref., sp.gr. 0.965-0.990	gal.	.70
Pine tar, ref., thin, sp.gr., 1.080-1.960	gal.	.38
Turpentine, crude, sp.gr., 0.900-0.970	gal.	1.30
Hardwood oil, f.o.b. Mich., sp.gr., 0.960-0.990	gal.	.35
Pinewood creosote, ref.	gal.	.49

Naval Stores

The following prices are f.o.b., New York, for carload lots:

Rosin B-D, bbl.	280 lb.	$17.00	—$17.50
Rosin E-I	280 lb.	17.85	— 18.40
Rosin K-N	280 lb.	19.75	— 22.50
Rosin W. G.-W. W.	280 lb.	22.50	— 24.25
Wood rosin, bbl.	280 lb.	17.00	— 17.50
Spirits of turpentine	gal.	....	— 1.97
Wood turpentine, steam dist.	gal.	....	— 1.70
Wood turpentine, dest. dist.	gal.	1.64	— ....
Pine tar pitch, bbl.	200 lb.	8.25	— 8.50
Tar, kiln burned, bbl. (500 lb.)	bbl.	14.50	— 14.75
Retort tar, bbl (500 lb.)	bbl.	15.00	— 15.25
Rosin oil, first run	gal.	....	— .91
Rosin oil, second run	gal.	.93	— .94
Rosin oil, third run	gal.	1.10	— 1.12
Rosin oil, fourth run	gal.	....	— 1.15

Solvents

73-76 deg., steel bbls. (85 lb.)	gal.	$0.33½
70-72 deg., steel bbls. (85 lb.)	gal.	.31½
68-70 deg., steel bbls. (85 lb.)	gal.	.30½
V. M. and P. naptha, steel bbls. (85 lb.)	gal.	.23½

Crude Rubber

Para—Upriver fine	lb.	$0.47½ —	$0.48½
Upriver coarse	lb.	.34 —	.35
Upriver caucho ball	lb.	.33½ —	.34½
Plantation—First latex crepe	lb.	.53½ —	.54½
Ribbed smoked sheets	lb.	.53½ —	....
Brown crepe, thin, clean	lb.	.48 —	.48½
Amber crepe No. 1	lb.	.53 —	....

Oils

VEGETABLE

The following prices are f.o.b., New York, for carload lots:

Castor oil, No. 3, in bbls.	lb.	$0.18 —	$0.19
Castor oil, AA, in bbls.	lb.	.21 —	.23
China wood oil, in bbls.	lb.	.23½ —	.24½
Cocoanut oil, Ceylon grade, in bbls.	lb.	.20 —	.20½
Cocoanut oil, Cochin grade, in bbls.	lb.	.20½ —	.23
Corn oil, crude, in bbls.	lb.	.19 —	.22
Cottonseed oil, crude (f.o.b. mill)	lb.	.19 —	.20
Cottonseed oil, summer yellow	lb.	.22 —	.27
Cottonseed oil, winter yellow	lb.	.24½ —	.25½
Linseed oil, raw, car lots	gal.	1.77 —	1.87
Linseed oil, raw, tank cars	gal.	1.70 —	1.80
Linseed oil, boiled, car lots	gal.	1.75 —	1.80
Olive oil, commercial	gal.	2.50 —	2.60
Palm, Lagos	lb.	.17 —	.18
Palm, bright red	lb.	.16½ —	.17½
Palm, Niger	lb.	.16 —	.17½
Peanut oil, crude, tank cars (f.o.b. mill)	lb.	.23½ —	.24
Peanut oil, refined, in bbls.	lb.	.27 —	.28
Rapeseed oil, refined in bbls.	gal.	1.45 —	1.68
Rapeseed oil, blown, in bbls.	gal.	1.60 —	1.70
Soya bean oil (Manchurian), in bbls. N. Y.	lb.	.19 —	.23
Soya bean oil, tank cars, f.o.b., Pacific coast	lb.	.17½ —	.20

FISH

Winter pressed Menhaden	gal.	$1.20 —	....
Yellow bleached Menhaden	gal.	1.23 —	....
White bleached Menhaden	gal.	1.25 —	....
Blown Menhaden	gal.	1.26 —	....

Miscellaneous Materials

All Prices f.o.b., N. Y.

Barytes, domestic, white, floated	ton	$35.00	—$40.00
Barytes, off color	ton	20.00	— 25.00
Blanc fixe, dry	lb.	.03½	— .04½
Blanc fixe, pulp	ton	30.00	— 50.00
Casein	lb.	.16	— .18
Chalk, English, extra light	lb.	.05	— .07
Chalk, English, light	lb.	$ .04½	— $ .06
Chalk, English, dense	lb.	.04	— .05
China clay (Kaolin), imported, lump	ton	25.00	— 35.00
China clay (Kaolin), imported, powdered	ton	30.00	— 60.00
China clay (Kaolin), domestic, lump	ton	10.00	— 20.00
China clay (Kaolin), domestic, powdered	ton	25.00	— 40.00
Feldspar	ton	13.50	— 18.00
Fluorspar, acid grade, lump, f.o.b. mines	net ton	30.00	— 35.00
Fluorspar, acid grade, ground, f.o.b. mines	net ton	35.00	— 45.00
Fuller's earth, domestic, powdered	ton	25.00	— 30.00
Fuller's earth, imported, powdered	ton	35.00	— 40.00
Pumice stone, imported	lb.	.03	— .06
Pumice stone, domestic	lb.	.02½	— ....
Shellac, TN	lb.	1.10	— 1.15
Shellac, D. C.	lb.	....	— ....
Shellac, V. S. O.	lb.	....	— ....
Shellac, Diamond I.	lb.	....	— ....
Shellac, orange, fine	lb.	1.25	— ....
Shellac, orange, superfine	lb.	1.20	— 1.30
Shellac, A. C. garnet	lb.	1.10	— ....
Shellac, bleached, bone dry	lb.	1.35	— ....
Shellac, bleached, fresh ground	lb.	1.10	— 1.15
Soapstone	ton	15.00	— 25.00
Talc, domestic	ton	16.00	— 60.00
Talc, imported	ton	60.00	— 70.00

Refractories

Following prices are f.o.b. works:

Chrome brick	net ton	80-90 at Chester, Penn.
Chrome cement	net ton	45-50 at Chester, Penn.
Clay brick, 1st quality fireclay	1,000	35-45 at Clearfield, Penn.
Clay brick, 2nd quality	1,000	30-35 at Clearfield, Penn.
Magnesite, dead burned	net ton	50-55 at Chester, Penn.
Magnesite brick, 9 x 4½ x 2½ in.	net ton	80-90 at Chester, Penn.
Silica brick	1,000	41-45 at Mt. Union, Penn.

Ferro-Alloys

All prices f.o.b. works.

Ferro-carbon-titanium, 15-18%, f.o.b. Niagara Falls, N. Y.	net ton	$200.00	—$250.00
Ferro-chrome per lb. of Cr contained, 6-8% carbon	lb.	.20 —	.40
Ferro-chrome per lb. of Cr contained, 2-4% carbon	lb.	.21 —	.50
Ferro-manganese, 70-80% Mn	gross ton	140.00 —	150.00
Spiegeleisen, 16-20% Mn	gross ton	40.00 —	50.00
Ferro-molybdenum, per lb. of Mo	lb.	3.00 —	3.50
Ferro-silicon, 50%	gross ton	85.00 —	95.00
Ferro-silicon, 75%	gross ton	150.00 —	175.00
Ferro-silicon, 10-15%	gross ton	45.00 —	60.00
Ferro-tungsten, 70-80%, per lb. of contained W.	lb.	1.25 —	1.40
Ferro-uranium, 35-50% of U	lb.	7.00 —	....
Ferro-vanadium, 30-40% per lb. of contained V.	lb.	5.50 —	7.00

Ores and Semi-finished Products

Chrome ore, 35-40%, Cr_2O_3	unit	$0.60 —	$0.85
Chrome ore, 48% and over	unit	1.00 —	1.25
*Coke, foundry, f.o.b. ovens	net ton	7.00 —	7.50
*Coke, furnace, f.o.b. ovens	net ton	6.00 —	6.50
Petroleum coke, refinery, Atlantic seaboard	net ton	.... —	14.00
Fluorspar, gravel, f.o.b. mines	net ton	.... —	25.00
Manganese ore, 45% Mn and over	unit	.50 —	.75
Manganese ore, chemical (MnO_2)	gross ton	60.00 —	70.00
Molybdenite, 85% MoS_2, per lb. of MoS_2	lb.	.75 —	.85
Tungsten, Scheelite, 60% WO_3 and over, per unit of WO_3	unit	9.00 —	15.00
Tungsten, Wolframite, 60% WO_3 and over, per unit of WO_3	unit	7.50 —	10.00
Uranium oxide, 96%	lb.	2.75 —	3.00
Vanadium pentoxide, 99%	lb.	6.00 —	....
Pyrites, foreign, lump	unit	.17 —	....
Pyrites, foreign, fine	unit	.17 —	....
Pyrites, domestic, fine	unit	.16 —	.17½
Ilmenite, 52% TiO_2	lb.	.02 —	....
Rutile, 95% TiO_2	lb.	.11 —	....
Carnotite, minimum 2% U_3O_8, per lb. of U_3O_8	lb.	2.75 —	3.00
Zircon, washed, iron free	lb.	.10 —	....
Monazite, per unit of ThO_2	unit	42.00 —	....

* Government prices.

Plant Materials and Supplies

In carload lots, New York, unless otherwise stated.

BUILDING MATERIALS

Portland cement, at dock, without bags	bbl.	$2.80
Lump lime, common, including container	300 bbl.	2.65
Common brick, at dock	M.	16.00
Yellow pine, 3x4 to 8x8, 20 ft. and under	M.	48.00
Yellow pine, 3x4 to 8x8, 20 ft. and under at Chicago	M.	50.00
Yellow pine, 3x4 to 8x8, 20 ft. and under at St. Louis	M.	40.00
Roofings, tar felt (14 lb. per 100 sq. ft.)	ton	70.00
Roofings, tar pitch (in 400-lb. bbl.) carlots	ton	21.00
Roofings, asphalt pitch carlots	ton	34.00
Roofings, asphalt felt carlots	ton	63.00
Roofings, slate-surfaced, per roll of 108 sq. ft. carlots		2.25
Roofings, slate-finished shingles, 100 sq. ft. carlots		6.00
Linseed oil, raw in barrels	gal.	1.75
Linseed oil, 5 gal. cans	gal.	1.90
Red lead, dry, 100 lb. keg	lb.	.13
Red lead, in oil, 100 lb. keg	lb.	.14½
Red lead, dry, 5 lb. cans	lb.	.15
Red lead, in oil, 5 lb. cans	lb.	.15½
White lead, dry and in oil, 100 lb. keg	lb.	.13
White lead, dry and in oil, 25 and 50 lb. kegs	lb.	.13½
White lead, dry and in oil ,5 lb. cans	lb.	.15

STRUCTURAL STEEL, MILL, PITTSBURGH

Beams and channels, 3 to 15-in.	100 lb.	$2.45
Angles, 3 to 6-in., ¼-in. thick	100 lb.	2.45
Tees, 3-in. and larger	100 lb.	2.45
Plates	100 lb.	2.66
Rivets, structural, ½-in. and larger	100 lb.	4.20
Rivets, conehead for boilers, ½-in. and larger	100 lb.	4.30
Sheets, No. 28 black	100 lb.	4.35
Sheets, No. 10 blue annealed	100 lb.	3.55
Sheets, No. 28 galvanized	100 lb.	5.70

For painted corrugated sheets, add 30c. per 100 lb. for 25 to 28 gage; 25c. for 19 to 24 gage; for galvanized corrugated sheets, add 15c., all gages.

INDUSTRIAL

Financial, Construction and Manufacturers' News

Construction and Operation

California

EMERYVILLE (Oakland P. O.)—The American Rubber Mfg. Co., Park Ave. and Walt St., has awarded the contract for the construction of a 2-story factory and power house, to R. W. Littlefield, 565 16th St., Oakland. Estimated cost, $100,000.

SAN FRANCISCO—The Schmidt Lithographing Co., 2nd and Bryant Sts., retained F. Whitton, 805 Exch. Blk., to superintend the construction of a 5-story addition to its lithographing plant. Estimated cost, $228,000.

WATSONVILLE—The Ferro Products Co. is installing a modern plant on Monterey Bay and the Southern Pacific R.R., for the production of 99 per cent blank metallic oxide, that will supply a carload every 24 hours.

Indiana

FORT WAYNE—The Ft. Wayne Wks. of the General Electric Co. plans to construct a factory between Anthony Blvd. and Winter St., for the manufacture of incandescent bulbs.

Iowa

BOYDEN—The city has awarded the contract for the construction of a sewage disposal plant in connection with the proposed sewer improvement and water-works, to Ward & Weighton, 516-17 Davidson Bldg., Sioux City, at $12,200.

DES MOINES—The Pittsburgh Des Moines Steel Co. will build a 1-story, 135x300-ft. steel shop. Cranes and fabricating equipment will be installed in same. Estimated cost, $100,000. Work will be done by day labor.

Massachusetts

HOLYOKE — The American Writing Paper Co., 9 Main St., will build a 1-story, 90x92-ft. manufacturing building. Estimated cost, $25,000. Work will be done by day labor.

MONROE—The Monroe Bridge Paper Co. has awarded the contract for the construction of a 1-story manufacturing plant at Monroe Bridge, to George H. Stebbins, North Adams. Estimated cost, $25,000.

Michigan

DETROIT—The Western Gear Mfg. Co., 1040 Scotten Ave., has awarded the contract for the construction of a 1-story, 40x80-ft. heat-treating plant on Scotten Ave., to the Lundblad Co., Penobscot Bldg., Cyanide furnaces, annealing ovens, tumblers etc., will be installed in same. Estimated cost, $25,000.

Missouri

ST. LOUIS—The Century Electric Co., 19th and Pine Sts., has awarded the contract for the construction of a factory, to Stone & Webster, 120 B'way, New York City. Estimated cost, $500,000.

New Hampshire

NORTH STRATFORD — The Warner Sugar Refining Co., 79 Wall St., New York City, plans to construct a sugar refinery. Estimated cost, $1,000,000.

New Jersey

HALDEN—The town plans to improve water-works system, including a reservoir, filter plant, 16-in. main, etc.

JERSEY CITY—The Air Reduction Sales Co., Pacific Ave., plans to construct a 4-story factory building. Estimated cost, $124,000.

TRENTON—The American Steel & Wire Co., Hamilton Ave., has awarded the contract for the construction of a 1-story 60x100-ft. steel mill on Hamilton Ave., to James H. Morris, 137 East State St. Estimated cost, $25,000.

TRENTON—The Puritan Rubber Co., [illegible] Ave., plans to construct a 1-story, 28x128-ft. rubber factory. Estimated cost, $7,500. J. O. Hunt, 114 North Montgomery St., engr.

TRENTON—The Star Porcelain Co., Muirhead Ave., has awarded the contract for the construction of a 2-story, 34x68-ft. porcelain plant, to C. R. Randall, 43 North Hermitage St. Estimated cost, $6,000.

New York

CHESTER—The village plans to improve its waterworks system, including a reservoir, filter plant, etc.

ROCHESTER—The city will soon award the contract for the construction of a 3-story, 304x321-ft. junior high school at Wilson Park. Chemical equipment will be installed in same. Estimated cost, $1,200,000. Address J. M. Tracy, supt. of public school bldgs.

North Dakota

MINOT—The city will receive bids about Feb. 15 for the construction of a sewage disposal plant. F. Bass, Minneapolis, Minn., consult. engr.; E. J. Thomas, city engr.

Oklahoma

HUGO—The city voted $75,000 bonds for the construction of filtration plant.

Ohio

CLEVELAND — The Cleveland Rubber Mold & Machine Co., East 17th St. and Euclid Ave., has awarded the contract for the construction of a 1-story factory on Warner Rd., to the Moss Iron Wks., Leader-News Bldg. Estimated cost, $200,000.

CLEVELAND—The Cleveland Welding Machine Co., West 117th St. and Berea Rd., will soon award the contract for the construction of a 1-story, 42x106-ft. blacksmith shop and welding room. Estimated cost, $50,000.

CLEVELAND—The Westinghouse Electric & Mfg. Co., West 54th St., will build a 1-story, 128x165-ft. foundry addition at 1228 West 48th St. Estimated cost, $50,000. Work will be done by day labor.

Pennsylvania

ESSINGTON—The Westinghouse Electric Mfg. Co., Union Bank Bldg., Pittsburgh, has awarded the contract for the construction of a factory addition, to Westinghouse, Church, Kerr Co., Inc., 37 Wall St., New York City. Estimated cost, $2,000,000.

PHILADELPHIA—The city has awarded the contract for the extension of the Queen Lane filter system, to Edward Fay & Son, 2 South Mole St., at $367,734.

PHILADELPHIA—The Franklin Process Co., 291 Promenade St., Providence, R. I., has awarded the contract for the construction of 2-story, 75x103-ft. addition to its present manufacturing plant here, to J. W. Bishop Co., 109 Foster St., Worcester, Mass. Estimated cost, $43,000.

PHILADELPHIA—John T. Lewis & Bros., Lafayette Bldg., have awarded the contract for the construction of a 1-story, 120x150-ft. paint factory on Aramingo Ave. and Cumberland St., to the Turner Construction Co., 1713 Sansom St. Estimated cost, $100,000.

Tennessee

CHATTANOOGA—The Somerville Iron Wks., Somerville, N. J., have awarded the contract for the construction of a plant for the production of cast-iron pipe, on a site near the Signal Mountain Line, to the Austin Co., West 102nd St. and Berea Rd., Cleveland, Ohio. The plant will produce about 50,000 tons of castings annually. Estimated cost, $1,500,000.

Vermont

ST. JOHNSBURY—The Cary Maple Sugar Co. is having preliminary plans prepared for the construction of a maple sugar factory on Portland St. Estimated cost, $150,000. Webster & Libby, 534 Congress St., Portland, Me., engrs.

Wisconsin

SHEBOYGAN—The Badger State Tanning Co., South Water St. and Maryland Ave., is having plans prepared for the construction of a 4-story, 60x250-ft. tannery. Estimated cost, $50,000 to $60,000. Juil & Smith, Irving Bldg., archts. Noted Oct. 22.

British Columbia

VANCOUVER—The Canadian Carbonate Co., 1050 Hamilton St., has awarded the contract for the construction of a 1-story, 95x60-ft. factory at 11th Ave. and Yew St., to Baynes & Horie, 836 Howe St. Estimated cost, $70,000.

Quebec

MONTREAL—The Dominion Glass Co., 285 Beaver Hall Hill, has awarded the contract for the construction of a 3-story, 52x52-ft. glass factory on Wellington St., to Church Ross & Co., 10 Cathcart St. Estimated cost, $25,500.

SHERBROOKE—The Howard Pulp & Paper Co. has purchased a 9½-acre site on the bank of the St. Francis River and is having plans prepared for the construction of a wood pulp mill on same. Estimated cost, $750,000.

Coming Meetings and Events

THE AMERICAN ASSOCIATION OF ENGINEERS will hold its fifth annual convention in St. Louis, May 10 and 11.

THE AMERICAN CERAMIC SOCIETY will hold its annual meeting in Philadelphia, Pa., Feb. 23 to 26. Headquarters are at the Bellevue-Stratford Hotel.

THE AMERICAN CHEMICAL SOCIETY will hold its annual meeting April 13 to 16 inclusive, in St. Louis.

THE AMERICAN ELECTROCHEMICAL SOCIETY will hold its spring meeting in Boston, April 8, 9 and 10.

THE AMERICAN ELECTROCHEMICAL SOCIETY, New York Section, will hold a meeting, Jan. 23, on "Cheap Cyanide and Its Disposition."

THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS will hold its spring meeting in New York, Feb. 16 to 19.

THE AMERICAN WELDING SOCIETY will hold a meeting at Witherspoon Hall, Philadelphia, Pa., Jan. 23, at 8 o'clock, at which four papers on welding will be presented.

THE NATIONAL FOREIGN TRADE CONVENTION will be held in San Francisco, May 12 to 15.

Industrial Notes

THE MORSE BROS. MACHINERY & SUPPLY CO., Denver, Col., announces that it is dismantling the complete 500-ton concentrator and 250-ton copper smelter of the Penn-Wyoming Co. at Encampment, Wyo. The 16½-mile Leschen tramway is also being prepared for shipment. The tramway was built in four sections of four miles each.

THE ELECTRIC FURNACE CO., Alliance, Ohio, added a number of installations during the last quarter of 1919 which are of special interest on account of the new type of equipment involved and the special alloys which are to be melted in these furnaces. Among other installations may be noted the following for melting brass: The Standard Sanitary Mfg. Co., Louisville, Ky.; Akron Bronze & Aluminum Co., Akron, Ohio; Union Brass & Metals Co., St. Paul, Minn.; American Hardware Co., New Britain, Conn.; Roberts Brass Works, Detroit, Mich.; Kayline Co., Cleveland, Ohio. Mitsui & Co., of Japan, have purchased a 105-kw. nose-tilting furnace of one-ton capacity, together with a special motor-operated casting table, so designed that metal may be poured directly into the molds. Similar equipment, but with three casting tables, has been purchased by the Parrish Tool Co., Cleveland, Ohio.

PROF. W. F. COOVER, head of the department of chemistry of Iowa State College, delivered the principal address on Jan. 14 at the dedication of the new chemistry building of the State College of the University of Montana, at Bozeman, Mont.

THE CARBONDALE MACHINE CO., Carbondale, Pa., has recently opened a branch office in the Ellicott Square Bldg., Buffalo, N. Y., in charge of H. J. Botchford.

THE ALBERGER CHEMICAL MACHINERY CO. of 50 East 42nd St., New York City, has been formed for the marketing of special machinery for chemical plants and the purchase and sale of new and used equipment. A. H. Alberger, formerly president of the Howard Iron Works of Buffalo, is president of the new company.